R/E

RESEARCH & ENGINEERING

FOR RESEARCH & DEVELOPMENT MANAGERS

JULY 1956

2 #7

THE FORMULATION OF PROBLEMS IN RESEARCH

HIGH VACUUM Everywhere in Industry

ORGANIZING A RESEARCH INFORMATION CENTER

THE CHALLENGE OF FRONTIER PRODUCTS DEVELOPMENT

"If You've Used High Vacuum

You'll Really Appreciate These New NRC High Vacuum Components"

"They'll make your life easier . . . your vacuum system more productive.

"Take this new **NRC Model 520 Alphatron® Ionization Vacuum Gauge.** Its six scales cover the range from 1000 millimeters to 0.1 micron with accuracy better than ±2%. It's especially suitable for use with recorders because drift is negligible despite wide line voltage variation. It's rugged. Jolt the head, subject it to vibration, you still get accurate readings, and it's less subject to contamination than any other high vacuum gauge.

"This new **A-2-P Air-cooled Purifying Diffusion Pump** has speed, blankoff, and forepressure tolerance ranking with the best two-inch diffusion pumps without the complications of a water-cooled system. What's more, you can air release it while it's still hot.

"The **NRC Rotary Gas Ballast Pump** equals any mechanical pump under *ideal* conditions but *continues* to do the same job even when pumping 100% water vapor or many other condensable vapors.

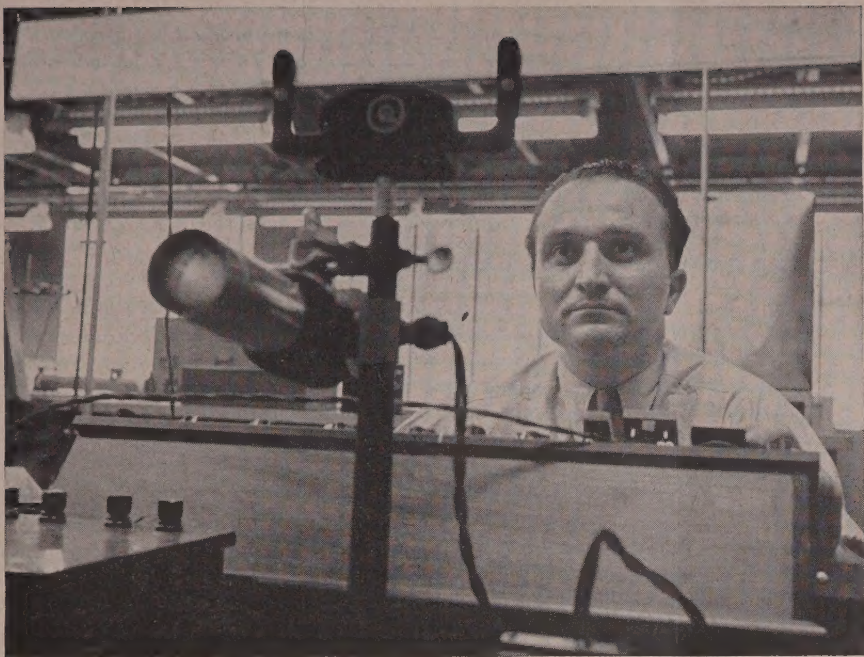
"We've found the importance of components like these through years of building and operating high vacuum systems and equipment. Why not take advantage of our experience?"

Other NRC high vacuum products include: analyzers, dehydrators, freeze driers, impregnators, gauges, metallizers, pumps, valves.

NRC EQUIPMENT CORPORATION

NRC EQUIPMENT CORPORATION
A Subsidiary of
NATIONAL RESEARCH CORPORATION
Dept. 247, Charlemont St., Newton Highlands 61, Massachusetts
Send me Data Sheet on Vacuum Gauges ☐ Diffusion Pumps ☐ Rotary Gas Ballast Pumps ☐
Have your representative call ☐
Name.............................. Title ....
Company..
Address..
City............................ Zone...... State..............

FOR MORE INFORMATION CIRCLE 1 ON PAGE 48



Scientist at control box of a Sanford-Bennett High-H-Permeameter measures hysteresis loop of Indox ceramic magnet.

How temperature affects magnets

An interview with Dr. Rudolf K. Tenzer, scientist, The Indiana Steel Products Company

BECAUSE PERMANENT MAGNET remanence changes, resulting from varying temperatures, often necessitate corrections, compensations, or allowances, Dr. Tenzer undertook a series of studies on the subject. Some of the data used by him in answering the questions posed below resulted from work sponsored by the Wright Air Development Center of the U. S. Air Force. Reprints of an article by Dr. Tenzer on the subject are available by writing The Indiana Steel Products Co., Dept. Q-7, Valparaiso, Ind.

Question: How does the remanence of permanent magnets vary with temperature?

Answer: Normally, remanence decreases with an increase in temperature . . . becoming zero at the Curie point, where all ferromagnetic properties vanish.

Question: Does a change in temperature result in a permanent change in remanence?

Answer: Not necessarily. Investigations which we have conducted show that temperature effects on ferromagnetic materials reveal both non-reversible and reversible variations.

Question: Can the result of these influences be evaluated?

Answer: Proper measuring techniques will evaluate the non-reversible variations as well as the reversible variations.

Question: Are non-reversible variations permanent changes in the remanence of a magnet?

Answer: Non-reversible variations are permanent until the initial remanence is restored by remagnetizing. This effect is not the same as irreversible metallurgical changes which prevent restoration of initial remanence by remagnetizing.

Question: What are reversible variations in remanence?

Answer: When a magnet has been stabilized for a certain temperature range, remanence variations within this temperature range are reversible.

Question: How are magnets stabilized for a given temperature range?

Answer: The magnet is exposed to repeated temperature cycling over a given range until the non-reversible variation becomes zero and remanence at room temperature remains the same for each additional cycle.

Question: Can the amount of remanence variation with temperature be predicted?

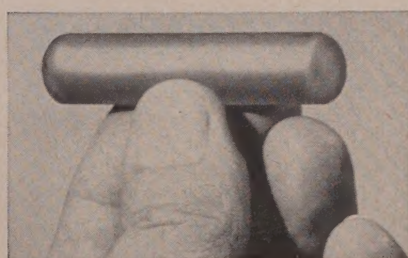
Answer: Our experiments in this field have produced quantitative results which can be used in predicting both the reversible and the non-reversible variations in remanence resulting from temperature change.

Question: Over what temperature range can these measurements be applied?

Answer: Our initial work in this field has been carried out in the temperature range from —60°C to 350°C.

Indiana expands research and production facilities

Currently under construction at Valparaiso, Ind., is a half-million dollar addition to the main plant of The Indiana Steel Products Co. The new structure will provide facilities for expanded research of magnetic materials, and increased production of Indox ceramic permanent magnets.



"Cattle Magnets" protect Bossie from stomach-aches

Cows often consume nails, staples and wire with their food. This causes a disorder called "hardware disease." To prevent it, you can feed Bossie an Indiana "Cattle Magnet." The magnet remains in her first stomach, gathering the stray metal. This keeps it from passing to her other stomachs (she has four, you know) where it can cause great distress.

FOR MORE INFORMATION CIRCLE 2 ON PAGE 48

JULY 1956

VOL. II NO. 7

RESEARCH & ENGINEERING

the magazine for research and development managers

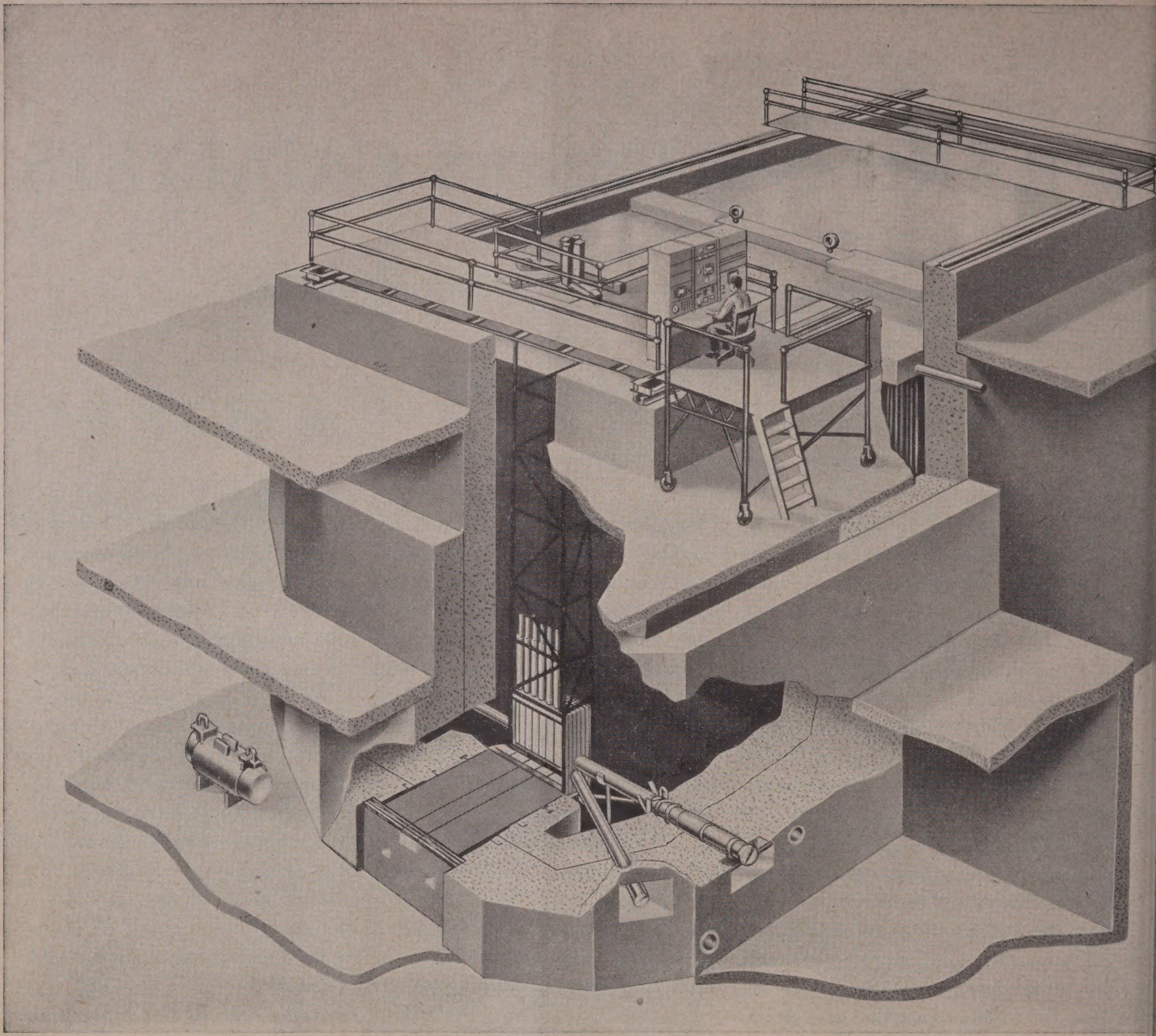
Publisher William H. Relyea, Jr.
Publishing Manager Walter L. Benz

FEATURES

DEPARTMENTS

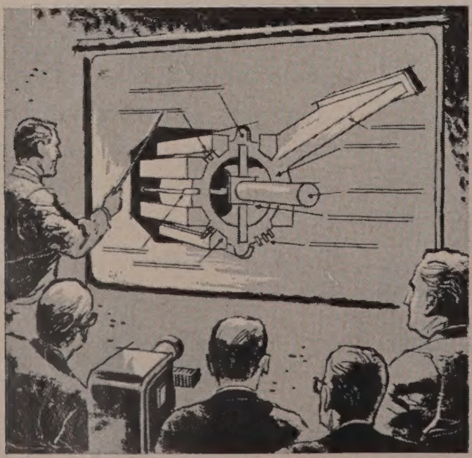
Editor Harold G. Buchbinder
Management Affairs Editor Luis J. A. Villalon
Associate Editor Samuel D. Hobbs
Associate Editor Melvin Mandell
Editorial Assistants Greta Laredo, Carol Negin, Martha Moffett
Assistant to the Publisher Martha Knowles
Art Director James Flora
Contributing Editors Merritt A. Williamson, James M. Beveridge, George L. Palken
Circulation Supervisor Ruth Reardon

RESEARCH & ENGINEERING is circulated to men of industrial research, development and design departments in all branches of industry and in government research installations. Subscription; U. S. A. and Canada, $10.00 annually: other countries, $20.00 annually: Single issue $1.00 when available.
Published monthly by The Relyea Publishing Corporation, William H. Relyea, Jr., President; Harold G. Buchbinder, Vice President. Executive, advertising and subscription office; 103 Park Avenue, New York 17, N. Y. LExington 2-0541. Editorial office: 77 South Street, Stamford, Conn., Fireside 8-7781. Unsolicited manuscripts must be accompanied by return postage. Although all reasonable care will be taken the editors assume no responsibility for their safety or return. All editorial communications should be sent to the Stamford Office. Published and accepted as controlled circulation publication at Orange, Conn.

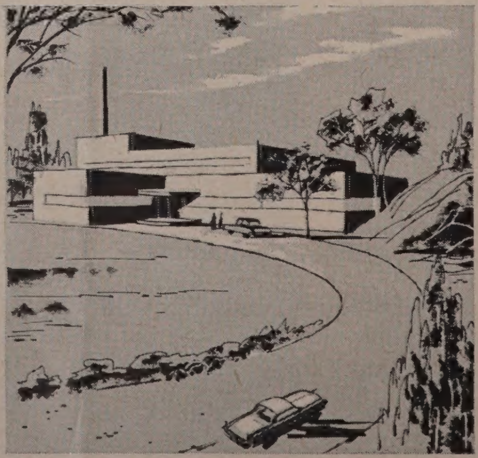


SWIMMING POOL REACTOR, one of three G-E research reactors available under the 7-point program, is designed to produce large quantities of neutrons. Its flexibility, safety features, and high flux potential appeal to universities and research organizations.

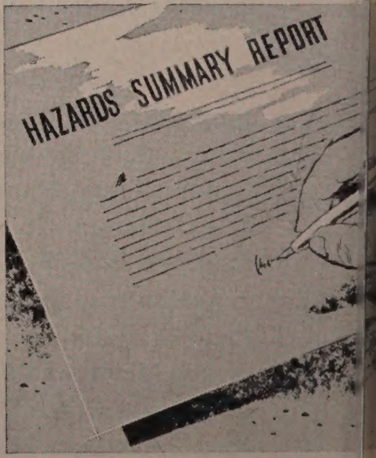
NEW GENERAL ELECTRIC 7-POINT PROGRAM:



1 REACTOR SPECIFICATIONS are prepared to meet your research requirements. These include details on core, control, and reactor components.



2 BUILDING STUDY also includes complete co-ordination of all plans for the many facilities required in the reactor and laboratory buildings.



3 HAZARDS SUMMARY REPOR[T] We help you prepare study f[or] submission to AEC Division [of] Civilian Application.

FOR MORE INFORMATION CIRCLE 4 ON PAGE 48

How General Electric can help you enter advanced nuclear research fields

New G-E 7-point program simplifies procedure for obtaining a nuclear research reactor

There is more work involved in obtaining a nuclear reactor for advanced research than simply ordering one. Specific research requirements must be determined beforehand, an appropriate design selected, and necessary AEC construction permits and licenses obtained. Other essential steps are covered in the program outlined below.

NEW GENERAL ELECTRIC 7-POINT PROGRAM is a plan designed to materially aid you in putting a research reactor to work. Through this program you can obtain any one of three General Electric research reactors: The Swimming Pool Reactor, Heavy Water Research Reactor, or the Nuclear Test Reactor.

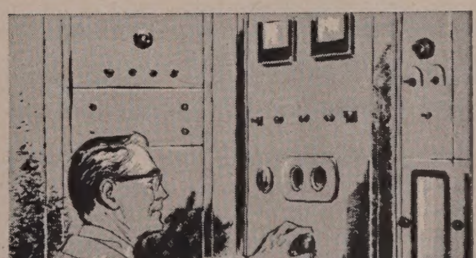
FOR MORE INFORMATION on these three research reactors and the new General Electric 7-point program, write for bulletin GEA-6326, General Electric Company, Section 191-1B, Schenectady 5, N. Y.; or contact your nearest G-E Apparatus Sales Office. Outside the U.S. and Canada, write to: International General Electric Co., 570 Lexington Ave., New York, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC

4 MANUFACTURE OF REACTOR is accurately co-ordinated with other onstruction plans, thereby assuring entralized project scheduling.

5 REACTOR INSTALLATION is supervised at the site by the men who have followed the design and manufacture of the complete system.



6-7 START-UP AND SERVICE under supervision of experienced personnel is added assurance that proper operation of your system will be maintained.

FOR MORE INFORMATION CIRCLE 4 ON PAGE 48

Letters

Engineer's Wife Talks Up

Cleveland, Ohio

Three times three loud cheers for the man (name withheld) who wrote the letter headed "Cavemen with Gadgets" in the April 1956 issue of Research & Engineering. This is undoubtedly one of the most intelligent pieces of writing to appear recently in an engineering publication—as an engineer's wife and a research director's secretary, I read a great many such magazines. Mr. Anonymous' example of the automobile as a symptom of our technology's failure to grow up is certainly a good one. The so-called "modern" car is perhaps the most ridiculous of all our gadgets from any viewpoint, and a striking example of Lewis Mumford's statement that we have used the machine as a "decoration" in our culture—that is, a large percent of our machines perform work that is out of proportion or irrelevant to real human needs. These needs will not be met as long as we continue to use our technology merely to serve the abstract and anti-human god of production-above-all; we will continue to wither away at the roots, and it will not be too long before our creativity, even in technology, will be completely atrophied.

Perhaps the greatest fallacy in our worship of our own technology is the ironic fact that in spite of all the "easy-do", chromium plated, supersonic gadgets we produce, we who are the most "fortunate" people in the world live in abject poverty as far as the most basic physical needs are concerned. These are: air, water, food and space. Our air is poisonous, our water polluted, our food so over-refined there is no nutriment left, and our cities crowded and chaotic. What a desert we have created with our marvellous technology!

"Progress" does not pile up according to an arithmetical progression, just because the wheels of industry turn. Producing and selling twice as many tractors this month than last month doesn't of itself prove a thing. Why don't we admit that our bigger-is-better philosophy and our inflated values long ago reached the point of diminishing returns?

The purpose of my letter is to second Mr. Anonymous in his very honest and intelligent appeal for a new direction in our thinking. Also I would like to urge you and your magazine to continue and intensify your efforts toward realizing a better kind of world from the one in which we now live. We certainly have the means; now let us use our technology to fill real human needs!

(Name withheld on request)

Accentuate the Positive

Philadelphia, Pa.

. . . although the positive side was mentioned ("The Difficult Personality Problem in R & D, (RESEARCH & ENGINEERING), April, 1956), it would seem to me that this article would tend to discourage anyone from doing anything except just [as he] was told for fear of becoming one of the horrible types shown. It would seem pertinent to emphasize that almost all of the types described are merely extremes of good and necessary qualities that a vitally alive man should have to some degree.

The following list is one possible expression of the character values of which the D. P. types are the extremes: (1) The Interrupter: Extreme of man with energy and ideas; (2) The Braggart: Extreme of the man motivated by pride of accomplishment, rather than material gain; (3) The Carping Critic: Extreme of the skeptic; the basis of all good scientists: (4) The Man-Who-Won't-Take-No: Extreme of self-confident producer; (5) The Firecracker: Extreme of the spark plug—the team driver; (6) The Dreamer: Source of radical ideas; (7) The Loafer: Wonderful guy to get along with; (8) The Excuse maker: Extreme of the careful scientist who has stuck his neck out to help before he could get all of the facts; (9) The Ailing One: Can be the extreme of an intense desire to excel; (10) The Soloist: Extreme of the contributor who wants to be right before he speaks; (11) The Sacred Rabbit: Extreme of healthy caution and realization of complexity of problems; (12) The Chameleon: Extreme of the coordinator of men with differing views; (13) The Bug on Detail: Extreme of man who sets high standards as guides; (14) The Stubborn Mule: Extreme of man with courage of his convictions; (15) The Bellyacher: Extreme of man who has honest criticism and offers it to contribute to team efficiency.

WALTER R. WILSON
Manager, Engineering Research
Switchgear and Control Div.
GENERAL ELECTRIC CO.

Remedy Worse Than Disease

Westfield, N. J.

I would like to disagree with Prof. Huxley Madeheim's comments (Developments, Page 9, *April, 1956)* on replacing engineers in management with business administration graduates.

Most engineers recognize that the route for fastest and furthest advancement in prestige and pay leads through supervisory and management jobs, and not in their own profession. Any appreciable dilution of advancement opportunities by hiring business graduates for administrative work would be a serious blow to morale, especially for younger engineers. Most would recognize the limitation when originally offered a job, or early in their career when they could easily find a new employer. The net result for any company who adopted this idea as a permanent policy would be a loss of some higher-caliber young engineers, and a worse shortage in the long run.

If management wants to keep engineers in engineering work, they must first make the profession more attractive, financially anc otherwise, than their own jobs. With this accomplished, the engineer shortage will disappear rapidly and the reverse situation—a shortage of business administration graduates to run the company and staff the sales jobs—will develop.

EDWARD H. BERG

Wool Gathering

Lawrence, Kansas

Can you tell me if anyone is manufacturing aluminum wool or aluminum in fibre form? It seems that I have read of such a product. I would appreciate also information about other metallic fibres.

MORRIS TEPLITZ
Research Chemist
RESEARCH FOUNDATION
UNIVERSITY OF KANSAS

(Note: If you have information that can be of assistance to Mr. Teplitz, please write to him at the address above.)

Variations on a Theme

Silver Spring, Md

I've just finished reading your excellent editorial "The Engineering Shortage: Real or Imaginary?" in the May issue of RESEARCH & ENGINEERING. I agree wholeheartedly with your comments—and, more than this, can offer proof that the situation is as you maintain.

A short time ago a group of engineers, including myself and associates, decided to see if a "shortage" existed. We are all qualified individuals, with a background of proven accomplishment; some with degrees, some without; some with 15 to 20 years experience, others comparative newcomers, but with heavy experience in specialized fields.

We made up detailed resumes and submitted them to various local and out-of-town firms who were advertising heavily for "Engineers . . . Scientists . . . Technical Personnel", each applying for jobs that suited his particular background.

There was one requirement. We all stipulated "minimum" salaries slightly in excess of what local beer truck drivers get (including commissions) and comparative to what automobile and real estate salesmen receive. That is, around $10,000 a year or more. Those of us who had outstanding records asked for $12,000 to $15,000 or $15,000 to $20,000.

In almost every case a "form" reply was received. The letters, from widely different firms, read so much alike that it was only necessary to change the letterhead—here is a typical letter:

"This will acknowledge and thank you for your resume, received in our office yesterday. We have carefully reviewed your application with several of our technical groups, but we find that at this time there does not seem to be an opening which would be suitable for a person with your particular experience and background."

Here's the pay-off—the firm sending this letter was advertising for men with "Guided Missile and Transistor Background". The man applying had this highly specialized background—and the firm continued to adverti[se]

FOR MORE INFORMATION CIRCLE 5 ON PAGE 48

Variations on a Theme,
cont.

for similar men after indicating there were no positions available!

Perhaps an even more important clue is in the letter itself. Note that the resume was "received in our office yesterday" yet they have "carefully reviewed your application with several of our technical groups". Fast work! Or perhaps the "review" consisted solely of noting the minimum salary requirement.

Locally, many engineers have private "black lists" of firms who advertise heavily, make glowing promises, but simply fail to consider paying salaries in excess of \$7000 to \$8000 a year, regardless of the individual's background.

From my experience with this group, and from my contacts with local engineers, I'd be willing to make a small wager. Given the authority, and a *reasonable* limit on salaries, I could recruit almost any desired number of qualified engineers and scientists in the local market. You name the number: 50, 100, 200! But I'd have to have the authority to pay salaries up to \$18,000 a year for exceptional men, and I'd have to have no artifical "yardsticks" to measure the men by, such as "must be under 40", or "must have engineering degree", or "must have green eyes, blond hair, and be over 6 feet tall". My "yardstick" would have to be *proven performance* only.

LOUIS S. GARNER, JR.
Technical Consultant

Ballston Spa, N. Y.

Your editorial was most appropriate and deserves widespread distribution. I graduated in 1950 and can testify to the peculiar employment situation at that time. And I can point to a number of middle aged engineers and scientists who are living examples of the necessity for job-hopping to avoid stagnation—including both those who did and those who didn't! The cries of "Shortage!" and frightening comparisons with Russian technical manpower get headlines all out of proportion to the situation.

LEWIS C. COOPER

Decatur, Ala.

. . . I must take the attitude that anyone who does not believe that the present engineering shortage is real is not fully conversant with the situation. In my company alone, we have 217 vacancies in the science and engineering field, despite desperate efforts made during the past five years to hire all of the qualified technical and engineering people possible. Last year, we recruited in Canada, in England, and on the Continent. This year we plan to do the same thing.

In going over your article, I am impressed with the fact that the dissatisfied engineers in the middle income group forms the basis for some feeling that there ma not be any shortage of engineer at this time. While there may b isolated individual cases where middle aged engineer has not bee able to obtain employment at reasonable salary, this is certainl not true of the great majority o engineers in this classificatio Again, in my own company we hav consistently hired chemists, chem ical engineers, and engineers i the 40, 50, and even 60 year ag groups at good salary levels. know of many other compani who are doing the same thing.

What is too often overlooked the fact that many middle ag engineers in the middle salar groups are in this salary classific tion simply because they are n worth more than the salary th are being paid. These men com prise a small, but very vocal par of the engineering profession. have been hiring engineers f over 20 years, and have come recognize the fact that many m in this classification do not have better job simply because they a not qualified for a better positio In a surprising number of case you will find that these men ha done very little, if any, studyi since leaving school and that, fro a coldly realistic standpoint, th are not worth as much to the employer as a recent graduate. hasten to add that this is n typical by any matter of mea but one encounters these situatio rather frequently.

I am aware of the fact th many engineers are working positions which do not require of their talents, and being pa salaries which are not adequate. one surveys the whole field, ho ever, and includes in this surv those in administrative and ex utive positions, I am confident th you will find that the average p of engineers compares favora with that in other professions.

I am completely in accord w the remedy which you suggest the next to the last paragraph your article, namely, a very su stantial increase in teachers' s aries. I will go so far as to s that teachers' salaries must be creased by 100% before they competitive with industrial po tions. I believe that we must w on this factor continuously if expect to improve the supply engineers available to Ameri industry.

FRANK J. SOD
Vice President, Research
Developm
THE CHEMSTRAND CORP.

Baton Rouge,

In addition to my teaching st ies in the College of Engineer at Louisiana State University also handle placement for the lege. I have been contending fo long time that there is really an engineering shortage, and majority of the companies all w the top half of our senior cl They are really interested in better student, and there are enough to go around. There i

hortage of good engineering graduates.

With the terrific amount of publicity on engineering shortage, we are attracting students that would ordinarily have never given a thought to engineering and do not have the aptitude for it.

I think the companies are making a big mistake in quoting the salaries they are quoting for graduating seniors. They really should be more concerned with the status of the average engineer that has been in their employ 10 or more years. At the present time, the gap between the starting salary and the salary of the 10-year employee is rapidly closing.

We certainly need more articles such as this if we are to combat the propaganda. . . . What is needed is a more realistic approach to the status of the engineer who has had considerable length of experience rather than the engineering graduate who is just starting out.

FRANK T. CARROLL, JR.
Assistant to the Dean,
LOUISIANA STATE UNIVERSITY
COLLEGE OF ENGINEERING

Los Angeles, Calif.

Your editorial in the May issue is one of the first presentations I've seen of engineers' real complaints. The main omission I notice is the lack of interest on the part of management in improving working conditions, even though an engineer in an office can certainly do more and better work than one in a 300 or 3000-man "bull-pen".

I must object to the idea that the attitudes mentioned are "normal" and "represent only a small fraction". The attitudes of the engineer are normal because he finds almost the same situation in every job. Industrial accidents used to be "normal" in certain industries, too. I suggest that the reason only a few engineers present these complaints is because there are only a few hardy souls who haven't given up as a bad job any attempt to improve the situation.

MERVIN E. FRANK

Jeffersontown, Ky.

May I indicate how thoroughly I agree with your editorial in the May issue. It completely represents my ideas on the subject and I believe if a true evaluation study were made, a great majority of the experienced engineers would concur with the findings in your editorial. Many of us are merely highly paid technicians and clerks. I trust you will continued to exert the full influence of your publication on this subject.

There is one point which I feel should also be brought into the open, namely the great number of people who for lack of a better term I classify as "pseudo-engineers". Many people throughout industry carry such titles as "service engineers," etc., who really have very little or no actual engineering training. Pray tell, how long could anyone who is not registered pose as an M.D.? This situation in the engineering profession, I feel, must be handled by our professional engineering societies and state registration boards. Possibly this subject could be covered by you in a future editorial.

(Name withheld by request)

Paoli, Pa.

Congratulations on your article, "The Engineering Shortage: Real or Imaginary?" in the May issue. May I have a reprint of that article? Your magazine is filling a large gap in technical periodicals by presenting fresh, thought-provoking material each and every issue. May I be added to your list of subscribers?

WILLIAM S. ASHMAN
Development Engineer
BURROUGHS CORP.

Seattle, Wash.

In these times of phoney ballyhoo about the shortage of engineers, it is particularly refreshing to find someone writing on the subject as realistically as you did. There is a very strong suspicion that the continued ballyhoo about the shortage stems from an understandable desire on the part of large companies to re-establish and maintain a buyer's market for engineering services. Unfortunately, most of the information on the shortage seems to have as a source people who would have the most to gain from a surplus of engineers—a practice hardly calculated to produce unbiased facts.

I would like to suggest that the real shortage which is so much in evidence is really a shortage of draftsmen and technicians with engineering degrees. As your editorial pointed out, the large demand for engineers is in a salary range—and this also defines an experience level—which supports this contention.

You make a point that there would be no real shortage of engineering manpower if even 60% of the engineering graduates in the past 20 years were still working in the primary field of engineering. I believe that this statement is too conservative. If only those engineers who today have engineering classifications and who are still working in the primary field of engineering were devoting at least 60% of their time to work which required education beyond the sophomore level, there would be at least 100,000 engineers in the country today looking for jobs. This is my most conservative estimate; I actually believe the number would be at least twice that large.

May I have permission to reprint your editorial in our publication, the "Northwest Professional Engineer"?

DAN N. HENDRICKS, JR.
President
SEATTLE PROFESSIONAL
ENGINEERING
EMPLOYEES ASSOCIATION

A Chicken In Every Lab

Admiral P. Clodius of the Roman Navy had a method for making decisions that we would like to recommend strongly to the Federal Trade Commission as a means for conserving time, energy and tax money whenever they are confronted with problems in scientific areas. Clodius's system was beautiful in its simplicity. He carried a crate of holy pullets and some grain in the hold of his ship. Before going into battle he would order the chickens brought up on deck and the grain distributed to them. Then, depending upon whether the chickens ate or abstained the Admiral would attack or withdraw. Unfortunately when he was about to attack the Carthaginians in the first Punic war his chickens were seasick and refused the grain. Whereupon Clodius, successful until then, ordered them thrown overboard, proceeded to battle and was promptly defeated. What better proof of the efficacy of the system is there?

Clodius's method would surely have been a better approach than the one used by the Federal Trade Commission in determining whether the battery additive AD-X2 marketed by Pioneers, Inc. of Oakland, California was worthless or beneficial. If you are unfamiliar with the story, here's a brief outline.

In 1952 the National Bureau of Standards at the request of the Federal Trade Commission and the United States Post Office tested the additive and found it worthless. In 1953 the Senate Small Business Committee, a committee that "views with sympathetic attention the problem of small business men who find themselves at odds with any government body which holds life or death power over them" held hearings on the matter. Secretary of Commerce Sinclair Weeks testified at the hearing. While going on record as not wanting to over-rule the findings of any laboratory, he also went on record—as a practical man—of wanting to take into consideration the "play of the market place". What appeared to convince him were the many testimonials of users that the product was good and that it saved them money. For that reason he felt the product should not be denied an opportunity in the market place.

During the hearings, Secretary Weeks dismissed Dr. Allen V. Astin, the Director of the NBS and then, as a result of public outcry, reinstated him. At that time he appointed one committee to study the work of the NBS and asked the National Academy of Sciences to appoint another committee to evaluate the Bureau's analysis of the battery additive.

After considering the Bureau's work as well as that of other conflicting and not as well controlled tests, the appointed committee upheld the findings of the NBS. Nevertheless last May the FTC apparently baffled by the "conflict" in scientific testimony dropped its charges. Although recognizing the "greater weight" of the scientific testimony on the side of the complaint, they put more emphasis on the consumer testimony in favor of Pioneers, Inc.

Personally, we favor chickens over consumers; if kept on land, free from organic diseases, they are apt to suffer less from psychosomatic influences. Upkeep, overhead and statistics (a 50-50 chance—more exciting than coin tossing, less gruesome than trial by fire) are in its favor. And what's more, the FTC's adoption of alectryomancy could possibly spread, thereby reducing the incidence of executive coronaries and ulcers induced by the continuous strain of decision making. With this chicken go, no-go system we should easily be able to postpone our coronaries and ulcers by at least ten to fifteen years before we have a normal right to expect them.

Chicken and corn, anyone?

Harold G. Buchbinder
EDITOR

FOR MORE INFORMATION CIRCLE 8 ON PAGE 48

Developments

Research in Land Locomotion

Half a century has elapsed since Best and Holt produced a commercial track-laying vehicle. Nearly the same length of time has passed since the Legislature of the State of Nebraska originated standard codes "to provide official tests for gasoline, kerosene, distillate or other liquid fuel traction engines . . ."

Since that time, millions of tractors and other off-the-road vehicles, both crawler and wheeled types, have been produced all over the world. The value of 1955 production approached the one billion dollar mark in the United States alone; and the accelerating construction of highways promises even greater expansion for the future.

And yet, if one compares a 1920 and 1950 track shoe, no major difference, either in the general concept or in the detail can be discovered. The same holds true for pneumatic tires which were applied to off-the-road locomotion in the late 1920's.

True, equipment has grown larger; reliability, economy and life span of engines, transmissions, tracks and wheels have improved. But performance of roadless vehicles measured in terms of its relationship to the soil has remained unchanged since the first Nebraska test.

In a dry sandy soil, for instance, a caterpillar tractor has never pulled more than approximately 75 percent of its gross weight, and a wheeled tractor approximately 40 percent of its weight. In a wet sticky soil with an appreciable content of sandy particles the pull may be increased for a crawler up to approximately 95 percent of its weight.

In general, a pound of vehicle weight pulls on the drawbar an average of approximately three-quarter pounds or less; whenever resistance to motion increases beyond that limit, the vehicle bogs down. Similar figures for aircraft or ship performance show that the progress of research and development in these fields has significantly increased lift/drag ratio; during the same span of time the weight/pull ratio of land vehicles has remained practically constant.

Research and Development of Motor Vehicles

These facts did not escape the attention of those concerned with research and development of motor vehicles. As a result, it has gradually been recognized that the whole problem of land locomotion must be re-analyzed and a new approach defined. This has led to the establishment of appropriate research and development at the Land Locomotion Research Laboratory of the Detroit Arsenal in an effort to solve the problems of how far to go and what the pay-off could possibly be.

According to Lt. Col. M. G. Bekker of the Land Locomotion Laboratory (author of *A Theory of Land Locomotion —The Mechanics of Mobility*, University of Michigan Press, Ann Arbor, Mich, 1956), it is clear that the gains from such research may be tremendous. If, for instance, the pu[ll] of a vehicle is increased radically, a much lighter tracto[r] can do the same work of a heavy vehicle. This would mea[n] greater economy, and it might boost competition withi[n] the industry much more than the advertising of trimming[s] and accessories.

Generally conceded is the fact that the cost of such re[-]search and development, presently at least, is very low. For example, tests made in a primitive sand bin at an ap[-]proximate cost of $15,000 have clearly explained the me[-]chanics of tractive forces as developed by a vehicle. Thes[e] experiments fully justified the abandoning of field tests originally planned for the same purpose with full-siz[e] vechicles, at a cost of several hundred thousand dollars.

What is the Real Problem?

What is the real problem in land locomotion researc[h] and development and what line of attack should be followed? Surprisingly enough, the problem of soil-vehicle relation[-]ship has never been explored in a way similar to that i[n] which the physical interaction was studied between air o[r] water and a ship. No textbooks or other scientific literatur[e] on the mechanics of land locomotion exist in contrast t[o] the wealth of information on aerodynamics and hydro[-]dynamics. There are no professionals in this new field sinc[e] colleges and universities center their curricula on auto[-]motive engineering around the internal combustion engin[e] and thermodynamics rather than around the applied me[-]chanics of a vehicle as such. Thus the problem must b[e] approached through a more basic study of the fundamental[s]

Load-Force-Resistance-Environment

In land locomotion as in sea and air transport, Col. Bekke[r] says that the ultimate question may often consist of how much load can be carried per unit of propelling forces re[-]quired to overcome the motion resistance in the given en[-]vironment. Thus, as the lift-drag ratio is a very genera[l] index of physical values in aviation or naval architectur[e] the weight/pull ratio may have the same significance i[n] land locomotion. Accordingly, it was assumed that futur[e] work should aim at a study of the mechanics of that rati[o] which has not changed radically for several decades.

If standard notions of soil mechanics as developed i[n] civil engineering are accepted as an explanation of thi[s] problem, it can be shown that the safe load (W) which ma[y] be supported by the soil is expressed by the following ap[-]proximate equation:

$$W = AcN_c + \gamma AbN_\gamma \quad (\ldots$$

where A is the size of the contact area between the vehicl[e] and the ground, and b is the width of that area; c is th[e] coefficient of soil cohesion; γ is the specific gravity of soi[l] and N_c and N_γ are numbers which depend on the friction[al] properties of the ground. These numbers have been com[-]

puted and are available in text books on soil mechanics.

On the other hand, it has also been shown that the pulling force (H) which may be developed by an agricultural tractor, for instance, is expressed approximately by the following equation:

$$H = Ac + W tan\, \phi \qquad (2)$$

where ϕ is the angle of soil friction; when dividing equation (2) by (1) the following expression may be obtained to determine roughly the pull/weight ratio of such vehicles which operate without much sinkage:

$$\frac{H}{W} = \frac{c + p\ tan\phi}{cN_c + \gamma\, bN_\gamma} \qquad (3)$$

where p is the so-called mean ground pressure equal to vehicle weight W divided by the size A of the ground contact area $(p = W/A)$.

Equation (3) explains the nature of the present stalemate: Pull/weight ratio (H/W) has not increased for decades because the ground pressure p must be kept low in order to prevent sinkage, which increases the motion resistance. Also, track width b cannot be made smaller than the limits so far acceptable as long as the prevailing design concepts exist.

Thus, any change in this impasse is possible only if either the present concept of a vehicle is radically changed, producing higher pull than that developed in accordance with equation (2) and shown in the numerator of equation (3), or if the detrimental effects of higher sinkage resulting from a p increase are so reduced that the sinkage will not necessarily mean an increase of motion resistance.

No Single Solution to the Problem

The problem is extremely complex and no single solution exists. There are a number of solutions and their value may be established only within a soils-vehicle system where operations research plays a primary role.

In general, it may be concluded that all these solutions are based on the development of more rational vehicle form concepts than those frozen during the past decades. It appears practically certain that a mere technological improvement of engines and transmissions will not radically change the present situation since it has failed to do so in the past. On the contrary, it has been demonstrated that a new type of wheel or track form may produce a radically higher pull than conventional tracks.

More systematic laboratory methods of research and development at the Land Locomotion Laboratory have superseded to a certain extent the costly, unprofitable empirics. Further savings in the development of motor vehicles may be realized if, for example, the already existing methods of testing vehicles by means of their miniature models become perfected. All this, however, would require the application of more rigorous methods to vehicle design and evaluation which, although already developed by the engineering sciences, are almost entirely unknown to the average tractor or automotive engineer.

Col. Bekker says that the development of what may be called a new applied mechanics, the mechanics of land locomotion, may now be in sight if the industries and universities embark upon this avenue of approach with a small portion of their financial and intellectual resources. The pay-off of such an approach may revolutionize land locomotion to the same extent in which aerodynamics has revolutionized the art of flying. Although the outcome of a new approach to the old problem of moving on the earth's surface will not be as spectacular as the wings of a moder Icarus, its significance and importance cannot be unde estimated.

Broader Vistas for the Engineer

Is a liberal education in the broad sense out of reach today's engineering student, whose career demands rigo ous specialization but whose position may involve gre social responsibility?

Engineering educators insist that the answer is "No."

After a three-year study, the American Society for E gineering Education has reaffirmed the vital role of studi in the humanities and social sciences in the training professional engineers. According to the ASEE's speci survey committee, the engineer needs both profession competence and a broad understanding of himself and the world in which he lives if he is to meet his growin responsibilities and realize his capacities as a human bein "He needs depth, flexibility and a capacity for growth directions which we ourselves can today dimly visualiz Like other professional men, he does not graduate fro college with a completed education.

"Given this view of the engineer as a professional ma and as a human being, the humanities and social scienc can take their place as an integral part of his total educ tion. They do not stand apart from the rest of the cu riculum."

Courses in the Humanities and Social Sciences

According to the ASEE report, engineering studen should spend at least one-fifth of their time studying th humanities and social sciences. A majority of schools not measure up to this standard; the national average something less than 17 percent.

Students should study both in the humanities and in th social sciences, said the committee. Semi-profession courses—subjects such as accounting, report writing, e gineering history and the like—do not meet the broa objectives. These are "surface skills"; humanities cours should deal with "subjects which, like science itself, a basic aspects of human activity in which depth of unde standing provides the only sound foundation for the st dent's further growth".

The committee dismisses fears that these studies humanities and social sciences must be superficial—or th they must jeopardize the technical competence of enginee ing graduates. "Leading engineering schools have demo strated that carefully planned programs provide a sour introduction to the humanities and social sciences whi simultaneously reinforcing students' engineering training

The non-literary arts seem especially well received amo engineering students. Literature teachers reported th

engineering students are "particularly adept at the analysis of ideas but less likely than other students to enter into the creative experience that is so important a part of the reading of imaginative literature".

But engineering students show "an exceptional interest in and understanding of music. They play music, listen to music and discuss music with an enthusiasm that sets them apart from most other students". Painting and the visual arts also seem especially attractive to engineering students.

More Than a "Cultural Veneer"

These studies of humanities and social sciences, said the committee, provide much more than "a cultural veneer designed to make the engineer acceptable in polite society. These studies contribute to professional competence in the broad sense of enabling the engineer to see his own activities in their human and social contexts, to understand his own objectives and problems in relation to those of men engaged in other activities."

Conflicts Between Arts and Engineering Faculties

The committee deplored the conflict which appears in some schools between arts and engineering faculties. "The sober truth," said the report, "is that the attitudes of the engineering faculty communicate themselves to engineering students. At institutions where the faculty exhibited the greatest belligerence about their colleagues in the arts, we invariably found the greatest student complaints about the work in humanities and social studies.

"On the other hand, we have evidence that the conflict disappears almost completely on those campuses where the arts and engineering faculties are thrown together as colleagues on an equal footing."

Selecting teachers for the humanities and social sciences in engineering schools is no simple task, the committee said. "Engineering students who are themselves moving out to the frontiers of knowledge deserve to be taught by men who are alive to new ideas and are able to demonstrate by personal example that no man's education may ever be considered complete."

Attracting and Holding Able Instructors

How can engineering schools attract and hold able and inspired instructors in the humanities and social sciences? Most teachers in these fields seek an environment where graduate students and active research projects give them many opportunities for scholarly development. The answer, said the committee, is to provide for each teacher an environment worthy of the disciplines in which he is trained, and in which he may develop personally and professionally.

Engineering schools may have failed to exploit some of their attractions for these teachers. "Able and enthusiastic instructors can be obtained if they are afforded professional careers. The special problems of teaching these subjects to engineering students provide an attractive challenge."

Projectitis: A New Disease?

A distinguished university president once diagnosed a "new disease" in these terms: "Projectitis . . . an unhappy addiction to limited objectives, perhaps at the very moment at which the individual should be broadening his own comprehension and deepening his knowledge of his discipline, with freedom for roving speculation in an atmosphere unencumbered by the pressures of problem-solving commitments to external agencies."

No drug, he said, had been discovered for "projectitis" and he offered no prognosis. The so-called disease has, if anything, spread to epidemic proportions at this date. so let us examine it closely.

Is it new, and is it a disease?

The warning on "projectitis" also described the alleged malady in terms of its converse: "self-powered inquiry," "free ranging," "spontaneous development." These are often applied not only to creative research but especially to the arts and literature. Here, from ancient times to the present,, "projectitis" is no stranger. Indeed, it has been directly responsible for some of the greatest creative works of history.

The example of the Medici and some of the Renaissance Popes comes first to mind. It was often on direct assignments from these patrons that painters and sculptors reached lofty heights of expression. In music, Bach, Handel, Haydn and others lived in much the same manner: subsidized to study and compose. The "contract" made the composer responsive to "projects" and he could and did exercise his genius to commemorate occasions from a coronation to a pleasure party sailing up the Thames. Many of those command performances have achieved a permanent place in musical literature.

Similar instances dot poetry, drama, and other aspects of literary endeavor. The creation of the King James Bible—as much a masterpiece of literature as of theological research—was an assigned government project; in fact, it was the product of that much-abused institution, the committee system. *(Continued on p. 16)*

The point is that scholars, scientists, and artists are not necessarily hindered or frustrated by the project system. On the contrary, assigned (limited) objectives on a "production schedule" may stimulate genuine achievement.

Many of the successful people in creative fields operate under pressures, often self-imposed, similar to those encountered in research projects.

Certainly the project method has been standard procedure for the engineer, from the Pyramids to skyscrapers, bridges, aircraft and automobiles.

Hence as an engineer I am reluctant to recognize the project as a disease. Rather, consider it a glandular function like perspiration. Though it can be a sympton of disease, more often it is the sign of constructive endeavor. To recognize that creative effort is often accompanied by pressure—even by discomfort—is just being realistic.

(Adapted from "Over the Director's Desk" by Harold K. Work, Director, Research Division, College of Engineering, New York University, Volume 6, Number 2 of the *NYU Engineering Research Review.)*

The Consultant: Objective Viewpoint, Expert Knowledge

A consultant may be defined as a specialist in some professional field, whose services are available for hire on either a part-time or full-time basis for assistance in the solution of technical or management problems. According to Dr. John F. Hofman, a consultant in his own right in the field of industrial statistics, more and more companies are turning to the consultant for temporary help on non-recurring problems which they are not staffed to solve. Such problems, he says, include establishment of production processes and quality control systems, research and development and other technical problems, market analyses, and many others.

Consultants can be divided into two broad categories: the individual who contracts for personal service to be performed, usually in the contracting company's facilities; and the consulting firm which contracts for the services of its employees, such services usually being performed at the consultant's facilities.

Why a Consultant?

Management's principal question is: "Why hire a high-priced consultant to solve problems that my staff is supposed to handle?" Hofman poses four answers:

- In many instances, a company cannot afford the high salaries of specialists on a full-time basis.
- In other firms, solutions to problems may be obtained only at the cost of diverting the efforts of company personnel from their important regular duties.
- To provide a staff capable of meeting all contingencies would overburden the company with full-time employees concerned with part-time problems.
- The consultant is usually a specialist whose talents (or staff) are geared to the efficient solution of specific managerial or technical problems. He contributes to the solution of problems by an objective viewpoint and broad experience from his dealings with the same problem in other firms.

The role of the consultant is chiefly one of putting out "brushfires"—solving problems of a non-recurring nature, relieving temporary staff overloads by temporarily taking on regular staff functions, and taking over "crash" programs where answers are needed long before consideration of the problem can be scheduled into normal routine. The consultant may organize an important service for the client and then turn its maintenance over to existing employees whom he may train.

When to Choose a Consultant

The ultimate basis for choosing between consultants and full-time employees is the relative costs. Consulting fees seem relatively high. A consulting engineer may charge \$8.00 to \$15.00 an hour compared to the \$3.00 to \$5.00 paid to employees in a similar category. However, when hiring costs, fringe benefits, and other overhead are added to the cost of maintaining a full-time employee, the balance will frequently favor the consultant. The problem of finding qualified personnel who can solve specific problems may also result in hiring a consultant for a more immediate answer. Finally, the cost of diverting available personnel from routine activities into special problems may make it advisable to call in a consultant.

(Editor's Note: For more information on the management consultants, see *The Management Consultant . . . Help for the Busy R & D Manager*, RESEARCH & ENGINEERING, May 1956, pages 30-34.)

Obsolescence and the Development Cycle

One great trouble of modern technology is that many of our free-wheeling thinkers seem obsessed with "progress" without pausing to realize that the opposite side of the coin of progress is "obsolescence". According to Corwin Willson, Director of Research for Corwill Corp., Lake Orion, Mich., "You can't have one without the other. But . . . our habits of thought have continued to cling to the habits and traditions of a pre-industrial era".

Willson poses this question: Where does obsolescence fit into the "development cycle"? He quotes K. Lönberg-Holm and C. Theodore Larson (authors of "Development Cycle", University of Michigan Press, Ann Arbor, Mich., 1953) as saying that "the development of any new form or activity pattern can be analyzed as a process comprising six characteristic and interacting phases: (1) research (analysis); (2) design (synthesis): (3) production (formation); (4) distribution (dispersion); (5) utilization (performance); and (6) elimination (termination)".

Obsolescence, say the Messrs. Lönberg-Holm and Larson, is linked with phase six, elimination. It is actually an index of cultural and technological progress and the problem is

the progressive removal of those things which become obsolete so that they will not stand in the way of our developing something new and better. "Unless things are subjected to some sort of 'time-zoning' and are eliminated when they reach the limit of their useful life-span, then they become obstacles to further desirable development."

Putting the Cart Before the Horse

In Wilson's view, we are putting the cart before the horse; for example, we are developing automation before we have developed more peacetime products better meeting the consumer's basic needs.

"What we call automation", he says, "is merely a more accentuated form of what has been taking place in our handicraft and largely agrarian economy for two centuries. The dynamic formula of the future is: A equals F, plus F_2 where A stands for automation, F stands for our growing freedom in time which is leisure, and F_2 stands for our growing freedom in space which is mobility. Already this formula heralds the four-day work week, and three-day weekends. Mass leisure can well provide a much greater growth potential than atomic fission. The paradox is that when men work less, they will buy more because they will have the time to need more, more time to use what they buy, and finally, what they need and buy will not be what they need and buy now."

Implications of the Development Cycle

The nature and implications of the "Development Cycle" are particularly pertinent to workers in the field of research and development, according to Willson. The development cycle can work effectively only if research itself is free to lead with a minimum of friction to the other phases of the cycle and if step six—elimination—is actually carried out.

Although Lönberg-Holm and Larson draw no such conclusions, our failures of elimination (of obsolete products, processes and methods) threaten us with a severe attack of mental and moral constipation, Willson thinks. "We have learned to cling to obsolescence in so many fields that we have made a virtue of 'conservatism'. Then we wonder why our friends abroad are becoming alarmed at our present dependence on defense expenditures to prop up employment." Willson says that this dependence stems directly from our failure to observe the elimination phase in the development cycle.

The "Depth" Approach to R & D Films

In most of its basic aspects, the art of producing engineering films is as different from the well-known Hollywood technique as the old-time stereoscope is from television's all-seeing eye. And in addition, it has overtones not to be found in the ordinary company or organization film. In short, while the equipment used to produce both is identical, the aims, approach and treatment are likely to be poles apart.

One reason why is that the *good* scientific film demands a "depth" approach to its particular problems; it can tolerate no superficiality. Another, according to Edward F. Cullen, head of Cullen & Associates, New York motion picture consultants and producers, is that scientific film-making demands more of the people who make them. The staff of Cullen's Scientific Film Division, for example, is selected on the basis of both its scientific background and training, and its proficiency in the motion picture art.

Cullen himself is a graduate physical chemist; he has been Chief, Munitions Division, Army Air Force Board, and Chief, Physical Vulnerability Division, Joint Chiefs of Staff. In his experience over the last five years, there are no routine assignments in the production of films for company research and development organizations. The Scientific Film Division explores through the camera's eye such diverse areas as basic research, product development, product engineering, and sales engineering. Industrial relations may also be touched upon in Cullen-produced films, if it relates to the management of such complex personality groups as are found in research and development.

Cullen says that the only way to insure successful scientific film-making is to have a meeting of the minds between the producer's representatives and the client company's scientists and engineers. According to Cullen, considerable rapport between the people who make the films and the people who buy them is built up, since they both speak the same language.

Cullen's standard practice is to survey the organization to determine how it would utilize a film for communication purposes, either within its own organization or for external use. The film or film program is then created and produced on the basis of the specific needs shown by the survey. The firm has found that with this approach, scientific accuracy and scientific understanding is much more likely to be assured in the film presentation.

Assessing R & D Costs: Five Key Questions

Each year, research and development managers are faced with the inevitable question, "What expenditures should we recommend for R & D in the next 12-month period?" There are probably as many ways of approaching the problem as there are R & D managers confronted by it. But one thing seems clear: The proper assessment of R & D costs, in relation to overall corporate goals, is one of the manager's most important—and difficult tasks.

To begin with, he is usually faced with a number of imponderables: the company's "forecast" of things to come, the nebulous state of some of his projects, and the balancing of basic and applied research efforts. Many criteria have been used as the basis for suggesting to top management the amount of money necessary to conduct the R & D program.

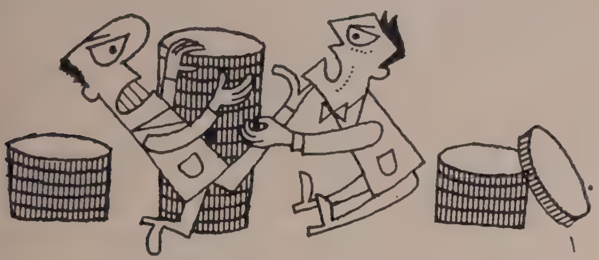
According to Vernon E. Cuneo, Controller, Chemical Divisions, Food Machinery and Chemical Corp., New York, some managers use the purely defensive approach of competitive parity—simply seeking to match what competitors are doing. Others use the simpler test of a given percent of sales. Still others feel the company should spend all it can afford. Anyone choosing the latter method should either have a lot of money, or a very productive R & D organization, or both.

As a rule of thumb, the R & D manager should bear in mind that each dollar spent for research today ought to result in the need for at least five dollars of capital expenditure for plants six or seven years from now. Unless the company is undertaking a program of basis research, there is usually no point in researching for plants or processes you can't furnish the capital to build.

As limiting factors on cost assessments, Cuneo says that each firm should look at (1) what it thinks it can afford

(2) what it can implement in the way of personnel and facilities, and (3) what it can finance as to future capital requirements. Then the company should spend enough, within these confines, to take on those projects that meet certain tests of profitability potential. In a sense, a company may need to "back into" its answer to this first important question.

Divvying Up the Research Dollars



How should an R & D organization divvy up the total number of research dollars available? How should the research dollar be divided between preliminary scouting or exploration, and process development and applications research? As to these latter segments, how should the money be divided among products presently made, products not made but produced by others, and completely new products? There are no quantitative answers to these questions. But in establishing an R & D budget, the manager should determine just how costs are to be projected in all these directions. He must judge whether, in his own case, he is "building the right activity balance."

Judging Individual Project Proposals

A third major question R & D managers should ask themselves in assessing research costs is: *"How do we judge individual project proposals as candidates for the research dollar?"*

To a large extent, the answer to this question involves the intangible judgments of intuitive men. But the R & D manager should require answers to certain standard questions before suggesting that the company embark on a project that may cost tens of thousands in R & D expenditures, and perhaps millions if it is successful and requires plant additions. The following factors may serve as an organized aid to judgment in controlling advance approval of the more substantial commitments of research funds:

• Carefully design and use a standardized project proposal form to evaluate both technical and economic factors.

• Try to foresee the maximum reasonable commitment you are taking on when you start.

• Determine for a stated period of say 10 years a measure of prospective sales and/or profits which you estimate are likely to result should the research program prove successful.

• Dilute your measure of sales or profit by applying a risk factor.

• Compare your thus diluted potential versus your cost estimates for R & D.

"Crystal-balling" chances of success at an early stage may be indeed a crude method. But Cuneo feels that it does offer some foothold, even if the future profit estimate is nothing more than a "royalty earned" measure, as for example, an arbitrary four percent of potential sales. While such guesses should not be used to straight-jacket decisions on R & D expenditures, they can serve the worthwhile purpose of helping the people involved to think through their problems in a more organized fashion. Relating prospective cost, potential and risk can be helpful to a company in minimizing the number of projects where a company simply "swims with the tide."

Providing Interim Evaluation

Here again, the R & D manager should pose certain guiding questions at periodic intervals, particularly at annual budget time or when a project goes from laboratory to pilot or from pilot to semi-commercial pilot stage. Nothing is sillier than to continue researching toward a potential that has disappeared because a market has vanished, or somebody has beaten you to the punch by patenting a better process.

Measuring Long Term Results

A fifth question, and a crucial one, is, *"How do we measure long term results from R & D?"* One technique for accomplishing this is to relate the statistics of net dollar sales and profits increase originating from R & D to the costs of the R & D program. Another way to measure results might be to estimate the amount of royalty your company would be willing to pay to an outsider for the use of the processes accepted by your plants from research.

An alert R & D manager will participate with the company's financial management in developing fair statistics and yardsticks to measure R & D performance. Similar cooperation is desirable in developing the practice of post completion review of individual project results.

Basic Figure Controls for R & D

What basic figure controls are required of R & D, both for budgeting and day-to-day accounting? Cuneo thinks that the R & D manager should certainly be able to label his costs by kinds of expenses for each organizational subgroup, as a means of overall control. The R & D manager must code his costs by project numbers, and the projects in turn should be subject to classification by categories of research activity—old products, new products, applications, process development, and also by major product lines.

European Technical Digests

The best articles from European technical and industrial journals, translated and digested, are now available monthly to American industry. The Organization for European Economic Cooperation, a multi-government agency set up to stimulate economic growth of member-nations, will distribute "Technical Digests", designed primarily for those interested in manufacturing and production. These digests will cover almost all fields of industrial interest.

Many of the articles in the periodical, which averages 140 illustrated pages, discuss new products and processes developed by European manufacturers. It contains only the most effective articles gleaned by specialists from over 1000 European periodicals.

Subscriptions are handled by the O.E.E.C. Mission Publications Office 2000 P St., N. W., Washington 6, D. C. The rates are $24.00 a year or $2.50 per single issue.

management affairs

Seven of the most popular articles for improving technical management published in RESEARCH & ENGINEERING in recent months have been reprinted, including five by Luis J. A. Villalon, our Management Affairs Editor. Available for 25¢ each, they are listed below.

LIMIT THEOREMS: Practical Tool for Project Evaluation

THE DIFFICULT PERSONALITY PROBLEM IN R & D

EXECUTIVE HEALTH: 14 Ways to Maintain It

TURN YOUR IDEAS INTO ACTION

HOW'S YOUR STAFF EFFICIENCY?

HOW'S YOUR ORGANIZATION QUOTIENT?

TIME MANAGEMENT FOR THE RESEARCH EXECUTIVE

Reprints of the above articles on management problems are available for twenty-five cents each. Send check or money order to Research & Engineering, *77 South St., Stamford, Conn.*

The Metaphysical Classroom

We stand in peril of ourselves.

That is the conclusion of John Jay Hopkins, president of General Dynamics Corp., in a commencement address at Pennsylvania State University.

"The recorded history of the world has been the history of the duality of man. From the perspective of (our) 'metaphysical classroom' it seems like some incredible play that chronicles with trumpets the degradation and brutality of man; actors and audience, alike, (are) ignorant that it depicts the failure of force as a method by which men and societies may get, and keep, the realities they seek."

Mr. Hopkins said that an impersonal or "metaphysical" viewing of history reveals a second failure: "That of narrowly selfish economic imperialism . . . based on exploitation of agrarian nations as sources of raw materials, and markets for finished goods."

"Basic socio-economic factors," said Mr. Hopkins, "are generating desperate demands for power, food, water, shelter, and clothing among these underdeveloped or 'have not' nations. First, exposure to Western civilization has taught them that cheap power automatically raises living standards. Second, the improved health standards of partial or incomplete industrialization have induced explosive increases in population without commensurate increases of food supplies. Third, underdeveloped nations such as China and India possess colossal mineral resources which, because of insufficient capital and untrained and inadequate labor, remain idle while multitudes living above and around these resources are constantly on the edge of starvation. Fourth, World War II, which brought about a general withdrawal of the great colonial powers, permitted a galvanic upsurge of native idealism and nationalism."

The New Industrial Revolution

In view of these facts, Mr. Hopkins said that three conclusions may be drawn: (1) "A new and world-wide industrial revolution of incredible magnitude is presently taking place; (2) *All* nations, whether democracies or dictatorships, are striving desperately for the same economic goal . . . the completely industrialized society; (3) The complete industrialization of the world is the essential, indeed the mandatory, economic and ethical act of our era."

From this, Mr. Hopkins said that it is possible to draw "a series of startling yet logical inferences about the future: First, in about 25 years all men and all nations, regardless of political differences, must be driven into interlocking industrial economies with *demanded* living standards equivalent to 1956 American living standards.

"Second, such interlocking industrial economies must be sustained by automatic and semi-automatic machines depende upon constant and limitless energy flo

"Third, the world's entire coal and p troleum resources will support these i dustrialized nations for less than one hu dred years.

"Fourth, only abundant *new* sources energy—atomic fission, atomic fusion, a solar energy—can fill the energy gap.

"Fifth, if the world is to utilize the new energy sources by the time the begin to run out, it must begin now to velop the scientists, engineers, technicia and economists who alone can develop a maintain the new energy supplies to s tain the completely industrialized societ

Abolition of Total War?

Mr. Hopkins said that "we are led exorably by these logical inferences conclude that growth of the industrializ world society may well result, *through t threat of economic oblivion,* in the achie ment of a moral objective: the abolition total war". But he feels that a police co trol must be continued that will deter a inhibit men and nations from crimi acts.

"This is so because the scientists, gineers and technicians—the human sources—required to develop an industr ized world cannot at the same time expended on . . . an atomic-missile to war."

Mr. Hopkins cited three other reas why the growth of an industrialized ciety may result in the abolition of to war: (1) "The material resources nee to develop an industrialized world can at the same time be expended on the struments of total war; (2) food prod tion, transportation, communication, ho ing, sanitation, medical technology, are fruits of industrial machines and pr esses . . . to destroy these machines processes would destroy the industrial ciety; (3) because intricate machine to make the machines that find and uti the world's material resources, we sho never again be able to . . . extract coal and oil, our iron and uranium o once the machine tools are gone."

Mr. Hopkins envisions an entelechy World Energy Community to be und written *by* all the nations of the world, all the nations of the world. The purp of such an organization, he said, would to put into effect a multi-lateral, mu purpose, multi-dynamic program utiliz the forces of atomic fission, applied so energy and perhaps later, atomic fusion

Fallout Strontium-90 Determin

Two chemists have developed a met of determining the amount of strontium deposited in bodies of water due to ato fallout. The technique could also be u to uncover contamination due to was from nuclear reactor operations. Si strontium-90 is biologically the most to of the fission products, it can be used

a measure of radioactive contamination.

Charles W. Stanley and Paul Kruger of Nuclear Science and Engineering Corporation conceived the technique. The Pittsburgh firm is a subsidiary of Norden-Ketay Corp. Since the amount of radioactive material in a large body of water like a lake or river may be too much diluted for available equipment to detect, concentration of the contaminant is necessary. Ion exchange offers a convenient and inexpensive concentration method. Strontium can be adsorbed on an ion exchange resin from large quantities of water and removed with small quantities of acid or complexing agents.

Soviet Aeronautical Scientists: "An Elite Corps"

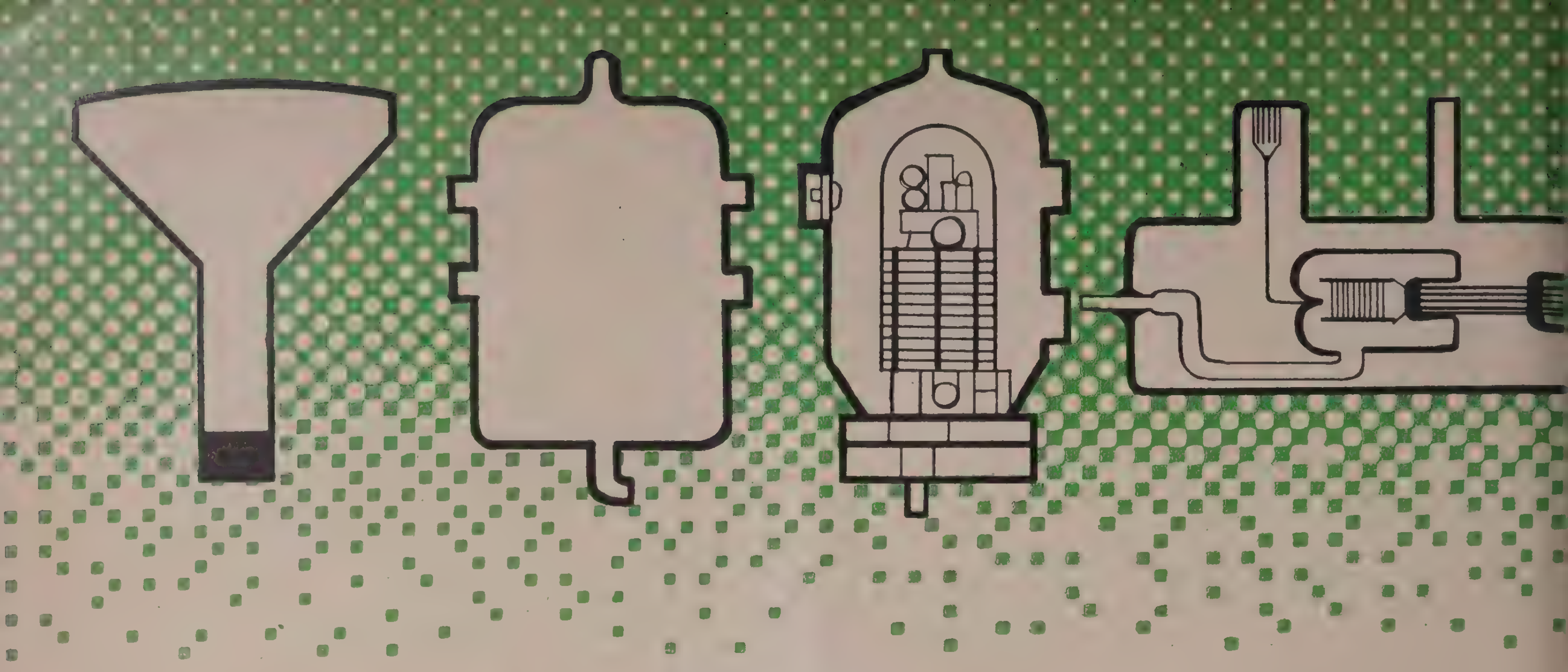
The Soviet educational system has trained a small but elite corps of aeronautical scientists who are second to none. But these top scientists are perched on a shaky engineering base, according to Dr. Leon Trilling, assistant professor of aeronautical engineering at M.I.T., who prepared a study on Soviet education in aeronautics.

"The full cross section of engineers in the Soviet Union," says Dr. Trilling, "have apparently not yet acquired that degree of engineering 'feeling' which only broad familiarity with machinery can give. They work by the book and require detailed direction."

Other highlights of the Trilling study:

- Because aeronautical engineering receives special attention in the Soviet, it probably illustrates their best efforts. However, it is subject to the same constant subordination of the individual to the national plan as in other areas. Despite this handicap, they have produced topnotch aircraft.
- The "vertical" approach to engineering education is used in Russia, as opposed to the "horizontal" approach in the U. S. The latter stresses versatility and fundamentals; it requires institutions which are independent of productive facilities. In the former, responsibility for the productivity of the nation is divided among a small number of powerful ministries, each of which has full charge of a definite segment of the industrial economy. Each ministry trains in its own institutes the skilled personnel—engineers, economists and others—needed for its operation.
- One of the chief weaknesses of the Soviet system is its inevitable duplication. A mechanical engineer of the Ministry of Air Production, for example, may be trained to design the same valves and piping as one in the Oil Production Ministry without any interchange of information between the two. Unfortunately, the same criticism of duplication between government agencies has been leveled at our guided-missile program.

FOR MORE INFORMATION CIRCLE 12 ON PAGE 48



HIGH Vacuum, Everywhere i

HIGH VACUUM

today

- *Protects materials against reaction with gases that are in the atmosphere*
- *Improves chemical reactions in which gaseous products form from solid or liquid reactants by maintaining low gas pressure over the reactants*
- *Aids evaporation from the surface of both liquids and solids at low temperatures by subjecting the material to low pressure*
- *Assists in studying and controlling the behavior of electrons and other subatomic particles by minimizing collisions with gross quantities of gas molecules. (This characteristic has led to the description of high vacuum as "the medium of electronics")*
- *Assists in avoiding the effects of gaseous conduction and convection in laboratory and production work*

The above functions of high vacuum are used in processes commonly referred to as:

drying, freezing, baking, casting, out-gassing, hermetic sealing, impregnation, distillation, evacuation, metal melting for purification, crystal growth, backfilling inert gas processing, metallic film evaporation, organic material evaporation, bombardment finishing of machined parts, ultra-frequency pulsing, leak testing, diffusion rate studies, porosity studies, time-temperature-vacua cycle data, and low density gas flow for aerodynamic studies in problems dealing with upper atmosphere flight.

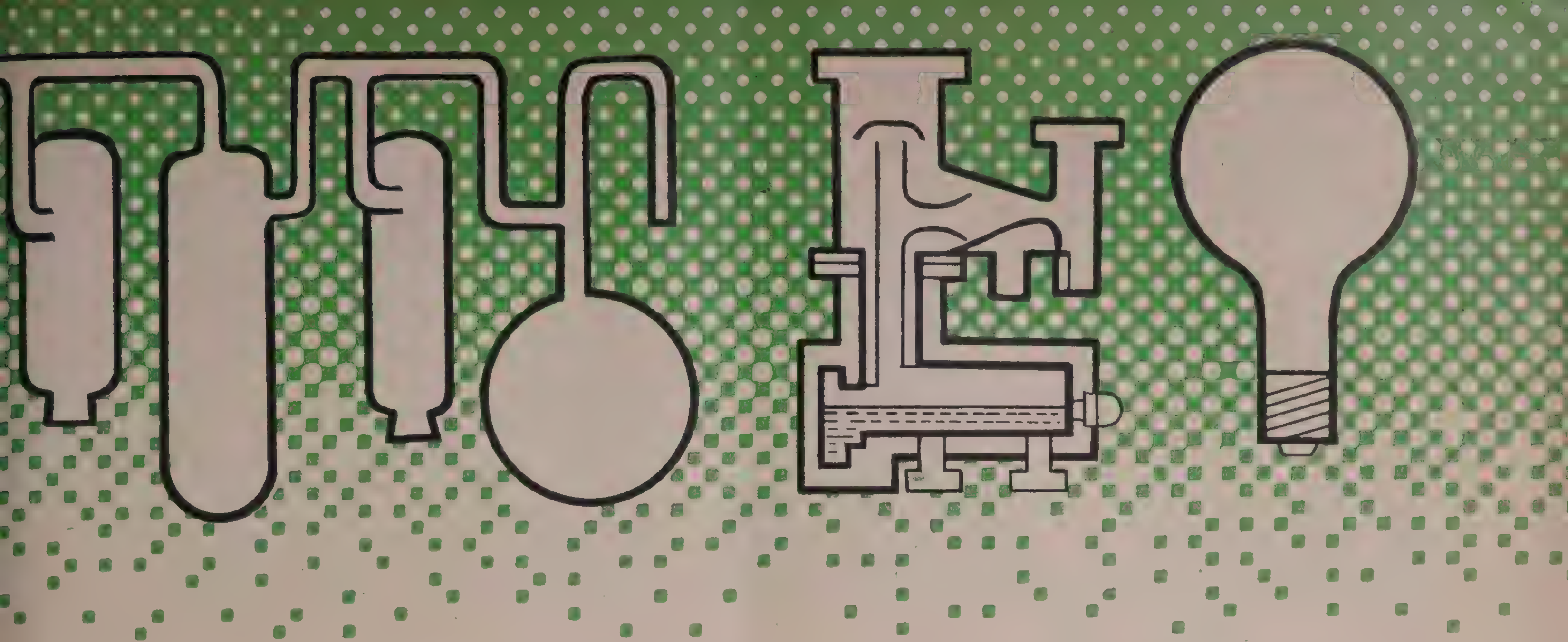
John H. Durante

High vacuum—absolute pressure below one millimeter of mercury or about 1/1000 or an atmosphere—is not an end in itself but simply a processing tool that delivers certain results. Like any departure from normal ambient conditions such as heating, cooling or high pressure, vacuum costs money. Necessary specialized equipment, operating cost and maintenance motivate the designer, the process engineer and the cost-minded manager to avoid its use where possible. Nevertheless, these same people have come to recognize its virtues and in many cases the availability of this processing tool has made possible a large number of wartime and postwar achievements in industrial process development. Conversely, vacuum techniques can improve numerous old processes in quality of product and in reduction in operating cost.

A study of the chart showing applications of high vacuum by industry and process indicates eloquently the inroads which high vacuum has made. High vacuum drying, distillation, extraction and concentration permit the chemical, food and pharmaceutical industries to operate successfully with heat sensitive materials. Special characteristics such as flavor, or in the case of pharmaceuticals, potency might be destroyed by exposure to higher temperatures which would be necessary except for the availability of high vacuum. In analytical techniques reliable vacuum systems have contributed to the high degree of acceptance accorded to analytical mass spectrometry, electron microscopy, vacuum fusion analysis and many other valuable laboratory techniques.

A veritable revolution is under way in the metallurgical process industry. Metals such as magnesium, lithium, calcium and sodium are produced using thermal reduction processes yielding product of high purity which would ignite and oxidize in conventional furnaces. Vacuum melting and casting of nearly the entire spectrum of metals from aluminum to zirconium gives cleaner ingots with improved physical properties. Performance of steels, high temperature alloys, precious metals and nuclear metals is improved by vacuum melting in terms of longer fatigue life, greater toughness and creep resistance, higher ductility and freedom from inclusions. Many refractory metals including titanium, zirconium, molybdenum, niobium, tantalum, as well as the rare earths could never be melted until vacuum furnaces became available.

The steel industry now utilizes vacuum induction furnaces up to



...dustry

High vacuum processes have matriculated from the status of a laboratory technique attempted only by advanced physicists and chemists to a full-fledged industrial tool. Here's a survey of the length and breadth of the industry — where high vacuum is used today and where and how it will be used tomorrow.

2500 pounds capacity and the titanium industry uses vacuum arc furnaces up to at least 4000 pounds capacity. In addition, a large number of small furnaces of both types are in use by various engineering outfits responsible for the producing chemically reactive metals for atomic power. Continuous vacuum arc melting has been the subject of considerable interest and in the not too distant future this problem will yield to the concerted efforts of economy minded engineers. As in any other industrial process, the cost of the product drops sharply with the change from batch type to continuous type operation.

The use of vacuum has also made strong inroads in metalworking and general manufacturing as well as in the electrical and electronics manufacturing industries. Again the removal of all atmosphere is frequently preferable to the use of special atmospheres subject to variation in composition and purity. The expense, or as the case may be, the hazard of inert or reducing gas atmospheres is thus eliminated. Vacuum brazed joints made without tarnishing the heated area require no subsequent flux removing operations. A higher percentage of vacuum brazed joints is free of defects which cause rejection of expensive subassemblies. Similar advantages apply to vacuum soldered and vacuum welded fabrications making it possible to join otherwise incompatible metals and achieve a degree of physical perfection hitherto unknown. Demands of the aircraft and electronic industries are becoming more and more challenging and exacting in this area. Some applications will demand vacuum brazing furnaces far bigger than now exist. New ideas are constantly being advanced and tried to meet the peculiarly difficult problems of design of very large vacuum chambers which will not collapse even at 2200°F.

Vacuum sintering is useful because it removes reactive gases from the interstices of the powdered compact thereby contributing to greater density and longer life of sintered parts which must withstand rigorous service as, for example, in carbide cutting tools.

Annealing is required both in the metallurgical industry, where ingots must be re-heated for subsequent fabricating operations, and in metalworking and general manufacture, where materials must be heated for forming, straightening and stress relieving. Use of vacuum in place of a conventional atmosphere assures a bright surface requiring no polishing or buffing in the finished assembly. It also removes hydrogen, a significant cause of embrittlement particularly in

HIGH VACUUM

tomorrow

The next three to ten years will witness the development of still broader use of high vacuum for a variety of processes and products.

ELECTRICAL & ELECTRONIC:

Evaporated metal films will be used to make low cost semiconductor devices.

Components, such as transistors, capacitors and resistors will be encapsulated in high vacuum to exclude the atmosphere to avoid deterioration.

Vacuum evaporated metallic and insulating films will be used to make complete low cost circuits with "built in" capacitors, resistors, and conducting paths. Photoelectric materials will be vacuum deposited for the economical production of solar energy collectors.

A glow-discharge method of measuring microwave power is now in the experimental stage at the Tube Laboratory of Microwave Research Institute. While preliminary studies indicate that this technique may not be as sensitive as bolometer techniques, there is no danger of burning out a sensitive element as in bolometers.

NUCLEAR:

Automated vacuum melting furnaces will cast fuel elements to precision shapes complete with protective coverings avoiding extensive handling and fabricating problems.

REFRIGERATION:

Compact, portable leak testing exhaust and dehydration units for installation of industrial and commercial refrigeration systems. Evacuated double walled cabinets will be used in domestic refrigeration for better insulation, light weight and reduced bulk.

PLASTICS & OPTICS:

Broader use will be made of decorative metallized plastic parts. Glass reinforced plastic automobile and appliance parts will be metallized to replace chrome plated metal.

Continued Next Page

HIGH VACUUM TOMORROW, cont.

Plastic sheet material used for packaging will have reflectant coatings to provide heat insulation and enhance appearance of merchandise.

Glass windows equipped with thin, transparent evaporated metal films will have electrically heated conducting surfaces to eliminate condensation and icing in extremes of temperature and humidity. Glass and plastic eyeglass lenses made virtually invisible with vacuum deposited antiglare coatings.

CHEMICAL, BIOLOGICAL & FOOD:

High vacuum distillation will be used to process synthetic organic materials for greater purity control of clarity. Vacuum dried human tissue and bones will be processed to provide "banks" for corrective surgery and accident cases. Preservation of animal sperm to permit cross inbreeding of animals to perpetuate desirable characteristics for beef quality and milk production. Vacuum concentrated whole milk will eliminate the cost of shipping and handling 80% of the weight and bulk of this product.

METALLURGICAL:

Continuous vacuum casting of steels, high temperature alloys, titanium and zirconium will be developed to provide lower cost end product.

The application of the gas turbine in highway vehicles depends to a great extent on promising alloys of common metals which will in all probability be vacuum melted. Continuous vacuum annealing of metal strip will accelerate the development of low cost applications of zirconium, titanium and other metals sensitive to contamination by atmospheric gases and hydrogen.

METALWORK AND GENERAL MANUFACTURE:

Applications of mass spectrometer leak testing will continue to grow, resulting in lower rejection rates and economy of production in every conceivable kind of fluid containing device. Assemblies of growing complexity will be vacuum furnace brazed, soldered or annealed. Such parts will need no further attention such as cleaning or polishing. Complex shapes of titanium, zirconium and high temperature alloys will be economically produced by vacuum casting.

PAPER, LEATHER, TEXTILE & WOOD:

Metallized coatings on paper will provide the decorative and functional effects of metallic foil laminates at lower cost.

Vacuum impregnated dyes in leather, paper and textiles will provide improved color fastness and resistance to fade.

Natural sap, resins and moisture will be removed from wood by vacuum extraction. Plastic will be substituted by impregnation to provide new materials combining the best properties of natural and synthesized materials.

Fabrics having one side metallized will be used in window drapery material to reflect outside heat in summer. The highly reflectant surface will be equally useful in winter to hold interior heat.

the highly stressed steel alloys as well as in titanium and refractory metals. Use of vacuum melting and heat treating operations has brought about the use of vacuum fusion gas analytical equipment for product quality control, and an adaptation of the analytical mass spectrometer for process control.

In paper, textile, leather and wood products industries, high vacuum contributes its share to improved processing techniques and novel converting operations which broaden markets for the products. Vacuum drying and impregnating in leather, paper and wood minimizes shrinkage or warpage and sets dyes. Textiles, vacuum coated with aluminum to reflect heat, give protection and comfort to those who must work in hot locations. Wood is vacuum coated to produce decorative effects. Vacuum metallized paper is beginning to find use as thermal insulation and in packaging application. These applications, where functionally equivalent to aluminum foil, appear to have competitive cost advantages.

In addition to the specific processes discussed, vacuum has "arrived" commercially for several miscellaneous uses. Pumping systems for exhaust purposes are used in the electronics industry for receiving tubes, cathode ray tubes, large power tubes. Vacuum exhaust systems are essential for particle accelerators used in research as well as in accelerators for materials testing and food preservation. Man's increasing preoccupation with flight in the upper atmosphere has required the simulation of high altitude conditions in the laboratory. Devices being built for operation at 250 miles altitude are tested at pressures of the order of 0.0001 millimeter of mercury, easily produced by commercial pumps.

Many industrial processes call for the flooding of a system with a particular gas or mixture. In such cases where air must be absent from the desired mixtures vacuum is used initially to purge the system of air molecules before filling with the desired gas. This technique offers greatly improved economy over the practice of repeated flusings.

One of the fastest growing applications of high vacuum is in leak testing. Small portable helium sensitive mass spectrometers are connected to vacuum systems which are used to evacuate vessels to be tested. Helium trace gas applied to the outside of the vessel is quickly inspired through any leaks present. The two part per million (helium in air) sensitivity of the leak detector, coupled with its almost instantaneous response, has resulted in the installation of systems to test devices ranging in complexity from multimillion dollar gaseous diffusion plants to the lowly water pail. Systems tested for leak tightness by the helium sensitive mass spectrometer method possess such "integrity" that it would take a matter of several months for a few cubic centimeters of gas to leak through at standard conditions. The mass spectrometer method, while requiring a high initial capital investment, has been found far more economical than cruder methods. Dependence on the individual to spot a bubble in a pressure-and-soapsuds test is out. The rapid response of the mass spectrometer method is ideal for a high production situation and minimizes the cost per test.

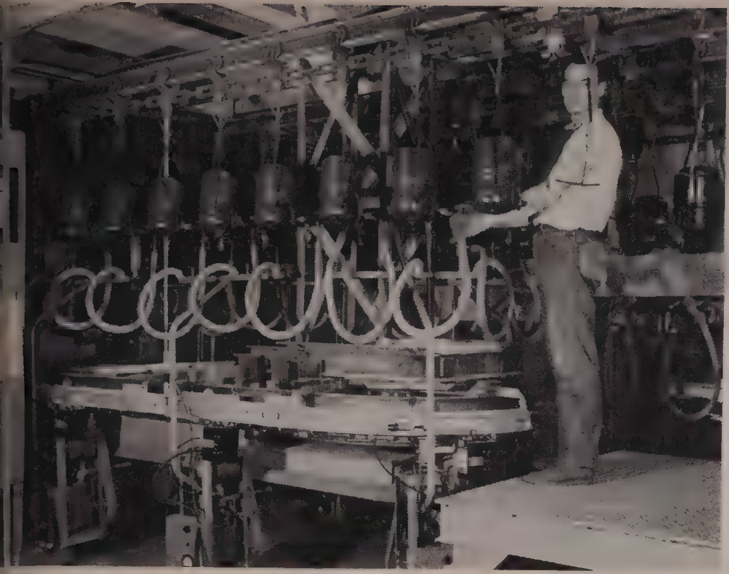
Perhaps the most commonly encountered result of the emergence of high vacuum as an industrial process is the vacuum evaporated or sputtered film. Both non-metals and metals can be applied to practically any smooth clean surface by heating to the boiling or sublimation point in vacuo the coating material. Vapor thus produced condenses on any surface exposed inside the chamber. Optical elements possessing antiglare qualities which improve their over-all high transmission characteristics owe their abilities to a vacuum deposited film of magnesium fluoride a quarter of a wave length thick. Use of coated optics on cameras retailing for a few dollars is indicative of the low cost of the process. Brilliant metallic films used for optical, decorative and sometimes electrical properties, are usually vacuum evaporated aluminum. Usual thickness of the vacuum deposited film is three to five microinches, several hundred times thinner than the average electroplated or sprayed coating. This characteristic makes evaporation a happy choice where scarce or expensive material is required for surface effects only, as, for example, a selenium coated rectifier plate.

Electronic Applications

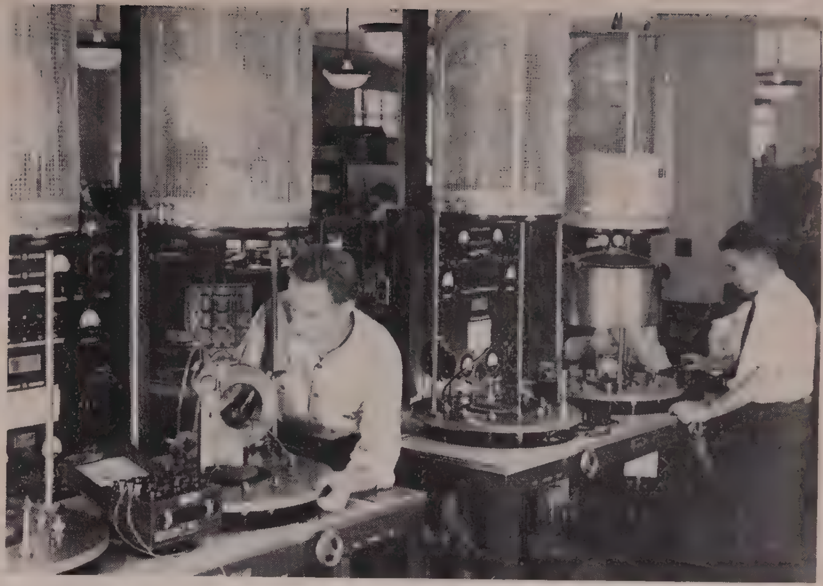
In addition to reflector application cited previously, aluminized television tubes provide increased brilliance and definition, thanks to vacuum evaporated coatings. Metallized paper and plastic film (Mylar) capacitors use less space than foil laminates and are self-healing. An extraordinary number of hardware, toys and novelty items are decoratively finished by this method. In 1955, 30% of the dollar volume of jewelry sold was vacuum metallized. The process, in addition to giving a higher finish, is less costly than electroplating. Another advantage is that it can be applied to nonconducting base materials such as injection molded plastics and even wood.

From this short review of principal uses of the high vacuum process in industry it can be seen that vacuum cuts across practically all technologies and industries. Fifteen years ago an occasional paper in the *Journal of the Optical Society* or the *Journal of Applied Physics* would deal with vacuum. Now it is frequently the subject of sessions in metallurgical, plastics, optical, chemical, pharmaceutical and general manufacturing professional and trade meetings. The tendency of vacuum to cross over these various fields led to the formation two years ago of the Committee on Vacuum Techniques, a nonprofit corporation whose purpose it is to provide a common meeting ground for scientists, production men and engineers whose duties involve the use of high vacuum processes. Several hundred attended the two symposia which have been held. Transactions have been published, providing much needed highly concentrated reference volumes on industrial high vacuum techniques. A third symposium will be held this year in Chicago on October 10, 11th and 12th.

Like refrigeration, combustion, high pressure and other industrial tools, high vacuum requires specialized equipment components. Mechanical pumps and steam ejectors, the prime movers for all high vacuum systems, are used to "rough" the system to a pressure of 0.1 millimeters of mercury absolute. Oil and mercury diffusion pumps, which sweep molecules from systems at the lowest pressures where mechanical devices are grossly inefficient, are



…ically sealed refrigeration compressors are mass spectrometer leak tested, dehydrated, …ged prior to charging with freon at York Corp. Gas ballast mechanical vacuum pumps …ing dollies below handle the water vapor load without condensers.*



A major step in making "Polyohm" resistors at Polytechnic Research & Development is done in these vacuum evaporation units. Batches of glass tubes are coated with a metal film and then varnished. Engineers examine different prototype machines for handling the tubes.

produced in sizes up to 32 inches inlet diameter with a choice of performance characteristics to meet the requirements of the application. Gages, both indicating and recording, special valves having nearly zero rates of leak as well as low impedence to the diffusion of gases at low pressures, seals and other components are available. Users desiring to construct their own systems will find an ample selection of components. Users wishing to take advantage of the accumulated experience of vacuum equipment builders who specialize in complete systems will find that it is possible to purchase as turnkey jobs, one ton semi-continuous melting furnaces, complete plants for the exhaust of color television tubes, installations for the impregnation of capacitors, automatic plants for the testing, exhaust, dehydration of hermetically sealed refrigeration compressors, vacuum metallizing units with associated equipment for laquering, baking, tinting and inspecting.

Some of the research involving the uses of high vacuum merits a glance because it gives a hint of future advancements in a number of fields.

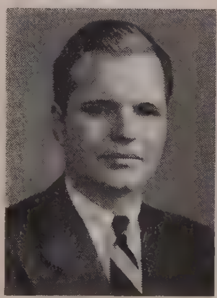
Several groups of workers are now engaged in ultra-high vacuum research employing pressure as low as 1×10^{-10} millimeters or lower than those presently attained in industry by a factor of 10,000. The problems of producing, maintaining and measuring high vacuums of this order are indeed formidable, but no more so than presently employed levels when first considered 20 years ago.

Availability of such a medium which begins to approach the classical concept of "nothing" will most certainly assist in the better understanding of nuclear and atomic physics. It may be possible to distill and purify metals at the temperature of boiling water which could lead to significant advances in solid-state knowledge. The close alliance between low temperatures and low pressures might be furthered using ultra high vacuum techniques. Continuously pumped double walled vacuum systems are used in cryogenics as insulation. Further progress toward the achievement of absolute zero may be another result of these investigations. END

General Vacuum Technology

Efforts will probably be started at the next meeting of the Committee on Vacuum Techniques in October to push global standardization of fittings, gages, valves and other components. Such Standardization will permit R & D labs greater flexibility in putting together equipment from different domestic and foreign suppliers and dispense with a current source of irritation.

At the same meeting, a domestic supplier of vacuum equipment may introduce a new, diffusion pump that will permit faster start and stop operatives for intermittent processes. The pump is also designed to avoid all oxidation of oil during the "stop" phase of its operation.



A graduate of Harvard in Physical Sciences, Mr. Durant has long been associated with the high vacuum field. He joined the National Research Corporation staff in 1943, as a research assistant in the Metallurgy Department, and served as Business Manager of the Research Division.

CHART OF VACUUM PROCESSES USED IN A VARIETY OF INDUSTRIES

	PROCESS																		
INDUSTRY	DRYING	DISTILLATION	EXTRACTION	CONCENTRATION	ANALYSIS	SUBLIMATION	REDUCTION	MELTING	CASTING	BRAZING	SOLDERING	SINTERING	WELDING	ANNEALING	EXHAUSTING	PURGING & DEGASSING	LEAK TESTING	IMPREGNATION	EVAPORATION & SPUTTERING
ELECTRICAL & ELECTRONIC	X									X	X	X	X	X	X	X	X	X	X
NUCLEAR					X		X	X	X	X			X	X	X	X	X		X
REFRIGERATION	X									X	X		X		X	X	X		
PLASTICS & OPTICS		X									X							X	X
CHEMICAL	X	X	X	X	X	X	X									X	X	X	
METALLURGICAL					X	X	X	X	X					X	X	X	X		X
FOOD & PHARMACEUTICAL	X	X	X	X	X	X									X	X	X	X	
METALWORK & GENERAL MANUFACTURE	X				X				X	X	X	X	X	X		X	X	X	X
PAPER, TEXTILE, LEATHER & WOOD	X		X		X											X		X	X

Herman Skolnick

Research is like a funnel. Vast quantities of information pour in, vast quantities pour out. Unless some organized, workable system of collecting, classifying and disseminating information is set up, research and development work is slowed — or brought to a dead halt. Whether you're in a large, small or medium-sized company, you can benefit from the author's tips on planning an R&D Information Center.

Planning an R&D Information Center

Information is something like health and wealth: It is most important to us when we don't have it. Just as a medical doctor cannot guarantee health or a sound economy ensure wealth, a supply of information cannot guarantee knowledge. But on the other hand, it is almost certain that the reverse—the absence of a doctor, the existence of a poor economy, and the lack of information—spells illness, poverty and ignorance.

The need for an adequate supply of information is especially acute in research and development work. Most such work usually only begins after someone diligently searched the literature to determine, among other things, whether previous efforts would make the project unnecessary.

To attempt to do research and development without adequate knowledge and facts is to repeat the past and to ignore the future. To think within the bounds of our formal education and training makes us artisans and our science an art. Therefore, wherever scientists and engineers constitute a population, as they do in the R & D laboratory, that environment must include the proper facilities for obtaining information.

It is true that these facilities may be highly informal and loosely organized. Nevertheless, some system does exist

and the larger the R & D organization becomes, the more imperative it is that thought be given to formalization of channels of information. What may not be much of a problem to the small lab today may become a big headache tomorrow as expansion occurs. It is wise, then, for the R & D manager to establish the means whereby the inflow and outflow of information can be accomplished speedily and efficiently. From a competitive standpoint it is important too, for more than one new product race has been lost because of lack of information, or misinformation.

There are many ways for an industrial R & D unit to provide its staff with "information operations and services" —a more formal name for this area of technical administration. But there is no one right way for all companies; furthermore, different divisions of the same company may employ different methods and procedures, although some central control and coordination is highly desirable.

At least one criterion should govern in every instance: Information operations and services must reflect the structure of the organization and its environmental needs. In other words, the organization of information operations and services should arise from each company's own recognition and analysis of what its needs and problems are. This represents the first step in setting up an information unit, for once such a study is completed, overall policies and procedures are clarified.

The R&D Information Center

In many companies, large and small alike, information requirements can best be served by forming an "R & D Information Center". Such a Center can act as a bridge over which external and internal scientific knowledge and facts are brought to and received from the staff. The remainder of this article will be devoted to how such a Center might be planned and organized, and to some of the problems encountered.

The Center's functions should be to accummulate and make available a collection of primary and secondary information sources to the staff to read and study as it wishes, and to communicate desired information to it as needed. To do this, the Information Center might include the information operations and services described below.

Library

A first-class scientific library is the core of all information work. The library comprises the functions of obtaining, classifying, arranging, safekeeping and circulating a specialized collection of books, journals, government specifications and publications, trade catalogs, patents and other published information. Services rendered by the library will differ according to the educational background of its staff, the size of the organization it serves, the size and accessibility of the library, the size of the library staff, and the scope of the other operations and services.

Smooth and efficient operation of the library requires the services of at least one trained librarian. Ideally the librarian should have a technical education, preferably a B.S. degree in the science important to the company, in addition to accredited library school training. Without the scientific background, the librarian would not be able to catalog and classify the collection effectively, nor would he be able to appreciate completely the importance of the library to the research and development function. The librarian might also tend to feel as an outsider rather than as a member of the team. However, for larger library staffs, it is not particularly important for each librarian to have a scientific background.

Generally speaking, the librarian is not primarily interested in the chapter and verse of each material in the library's collection. The good librarian is aware of the contents of each item, but is not a student of the contents per se. Consequently, the choice of technical books, journals and other items, although involving the librarian, should be left to the scientists in the Information Center. Some companies use a library committee composed of members of the laboratory and engineering staff to evaluate recommended purchases. Other companies allow the librarian to purchase any item asked for. Each company needs to resolve its own procedure.

No industrial library can hope to have in its collection every item of possible use to the staff it serves. One of the most important functions of the librarian is his role in inter-library loans, a service set up cooperatively by librarians for the borrowing and lending of references among themselves.

The librarian should be exceptionally proficient in handling a variety of reference questions. Many librarians consider this as their most professional function. In any organization, it is a good idea for the library's clientele to discover the scope of the librarian's abilities. It would not harm the librarian, either, to advertise what kinds of reference questions he can handle. Where the library is one unit in an Information Center, the division of labor should be well defined and understood by the laboratory staff.

An important publication of the library is the Accessions Bulletin. This is the library's medium for telling its users of new additions to the collection—books, journals, etc.

Research Report Files

The most permanent reflection of industrial research and development work is comprised of the records of experi-

ments and results. The accumulation of these records represents the most unique literature in an R & D organization's possession; they provide all the significant details of the company's technical past, present, and future. And they support the company's patent structure.

Research records and reports in some companies equal or exceed the space requirements of the library. Because of their importance, they require considerable planning and administration to ensure proper control. Suitable mechanisms must be devised for the Report Files to receive automatically every internal document of importance to the R & D function, to safely store the documents, and to control the circulation to those who need to know the contents.

There are several ways for arranging the collection of R & D records and reports. These methods include accession number, R & D classification, project classification, author, date, or combinations of the foregoing. Each company should analyze its own operations and determine which system best serves its needs. The most important consideration in choosing an arrangement system is the need to refer to and retrieve the documents.

Clerical personnel, under the supervision of a technical person in the Information Center, ordinarily should be able to discharge the services connected with the receipt, storage and circulation of materials in the Research Report Files.

Correspondence Files

Correspondence received and written by the staff is another unique and important information source in an industrial R & D unit. However, correspondence to be filed excludes that relating to purchasing personnel, medical, accounting, and the like, which should be kept separately.

All correspondence arising from research and development, sales, process research and certain phases of technical administration, should be received directly by the Correspondence Files Supervisor. Each correspondence should be entered, classified, charged out, and circulated to the addressed receiver and other members of the staff who have a need for the information.

Correspondence Files can be an extensive operation as well as one that requires considerable space. Consequently, retention schedules for each category of correspondence should be carefully established. Particular attention should be paid to the proper evaluation of correspondence that conceivably could be important to the patent function. Because industry places a premium on prompt communication, scientists and engineers will often use letters and memorandums to transmit experimental data. Such correspondence Files are brought to the attention of the Information Center Staff for possible indexing.

Research Report Indexing

Since records are the most permanent consequence of industrial R & D work, a key must be provided for communicating the contents. The generation and accumulation of these records constitute an important storehouse of company knowledge and know-how only in relationship to the ease of their retrieval at the time of need. A system must therefore be set up for the report indexers to receive from all geographical locations in the company every report written or received by the company which is pertinent to the total R & D effort. The report indexers' responsibilities are chiefly to abstract, index, maintain a Report Index File, and handle reference questions on the contents of the Report Files.

In order to handle this operation effectively, the report indexer should be a scientist or engineer who is aware of the company's interests. He should personally know the scientists and engineers producing the reports and should consult with them on their needs in retrieving the information contained in the report literature. The product of the report indexer's labors should be a Chemical Abstracts, Engineering Index, or Physics Abstracts of the company's internal knowledge and know-how.

Translating

Information is intelligible only to the degree that one knows its language. This is sometimes difficult enough for information written in one's mother tongue. Less than 50 percent of the world's scientific information, however, is in English. Broadly speaking, scientific publications are published in at least 40 important languages. Since there is no universal language and since machine translation is only a faint hope at this time, the R & D staff needs a translator or translators who are expert in the six to twelve most important languages and who are sufficiently educated in science to render the translations.

Literature Searching

A vital activity of research and development is the literature study prior to and during a laboratory investigation. A Literature Research Group should not displace the laboratory scientists's obligation to use the literature and to conduct his own searches. Rather, its primary objective should be to assist in this phase of research by compiling bibliographies for and extending literature searches prepared by the laboratory scientist. The evaluation of R & D problems against the known literature by a literature expert often can contribute to a solution.

Generally speaking, searches delegated to scientists in the Information Center should be those which will benefit many staff members on a project, those originating from plants and sales offices, and those originating from research and development management for background information.

Current Literature Bulletins

One of the phenomena of science is the exponential growth of its published literature. In order for an industrial chemist, for example, to keep abreast of developments and advances in his field, he needs access to about 500 journals issued weekly or monthly. A chemist searching this flood of literature and reading only the pertinent articles would have little time left for research.

Setting up a Current Literature Group is an efficient answer to the laboratory scientist's literature problem. All the journals received by the library are sent to scientists and engineers in the Current Literature Group for scanning. Articles of interest to the company's R & D staff are indexed and abstracted. The abstracts are then assembled and issued in a weekly Journal Reference Bulletin to staff members. Means are provided in the Bulletin for requesting the articles or journals from the library.

In addition to handling the Bulletin, members of the Current Literature Group should be aware of specialized interests of the R & D staff, bringing to the attention of individuals such articles not going into the Bulletin. The Current Literature Group should also be responsible for ordering all patents of interest to research and development, indexing and abstracting the patents, and assembling and issuing the abstracts in a Patent Bulletin.

Editorial Functions

The research report is a vital communication between the bench man and management. In addition to preparing such reports, most R & D staff members are conscious of

their need to publish or present papers at meetings. These important communications activities place a burden upon each company to strive towards uniformity, consistency and excellence in the writing problems of their employees. A technical editor is often the answer to these problems; he bears the responsibility for teaching and helping those with writing difficulties. He should also maintain uniformity and consistency in reporting research results, and arrange for company release of papers for publication or presentation. The technical editor may also handle the writing of booklets and special technical publications for R & D management, or serve as the nomenclature specialist for the entire company.

Other Services and Operations

The services and operations described above are by no means a complete list. For many companies they may far exceed needs, and certainly those not required should not be considered. On the other hand, the needs of some companies might dictate setting up such additional services and operations as a mathematical or calculating section, a cost estimating section, a corrosion data section, a product or material specification section, a company products data section, or a competitive products data section.

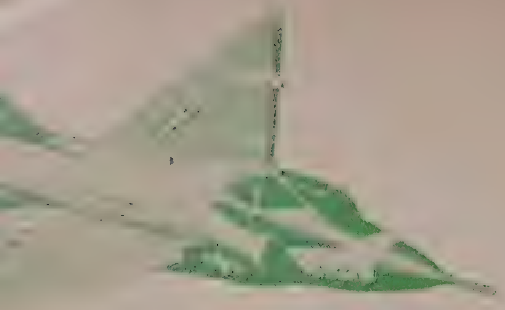
Documentation Research

Because of the growing difficulties of getting desired information from the mass of company and published literature, a certain amount of the information staff's time should be devoted to documentation research. New tools and concepts are needed to correlate data and to retrieve desired information. New procedures need to be investigated to determine how information is used by scientists and engineers in the creative stages. An Information Center neglecting research in these areas is not responsive to the company's requirements.

Advantages of an Information Center

This story is not complete, however, without summarizing the advantages of the hypothetical R & D Information Center described. For one thing, such an organizational unit makes the most of specialization and flexibility by bringing together an information team of scientist, engineer, librarian, translator, and technical writer. Each of the several groups in one administrative division has one line of incoming communication, so that the right person is easily assigned to the right problem without duplication of effort. Impairment of job interest by overspecialization is avoided among the information specialists by reassignments within the division. The information specialists are thus made more versatile and of greater service to the company. An integrated Information Center is also more sensitive to the requirements of the company than are information services separately. END

Dr. Skolnik, manager of the Technical Information Division at Hercules Experiment Station since 1954, is currently involved with plans for a million dollar Information Center to house his 28-member staff, of whom 15 are chemists and 3 librarians. His industrial experience includes ten years in charge of Literature Research in the Division, two years as a research chemist in the Hercules laboratories, and prior engineering and chemical experience in the petroleum and coal-tar industries. He is an active member of the American Chemical Society, American Documentation Institute, and Special Libraries Association.



THE CHALLENGE OF FRONTIER PRODUCTS RESEARCH

William E. Hill and Warren B. Riley

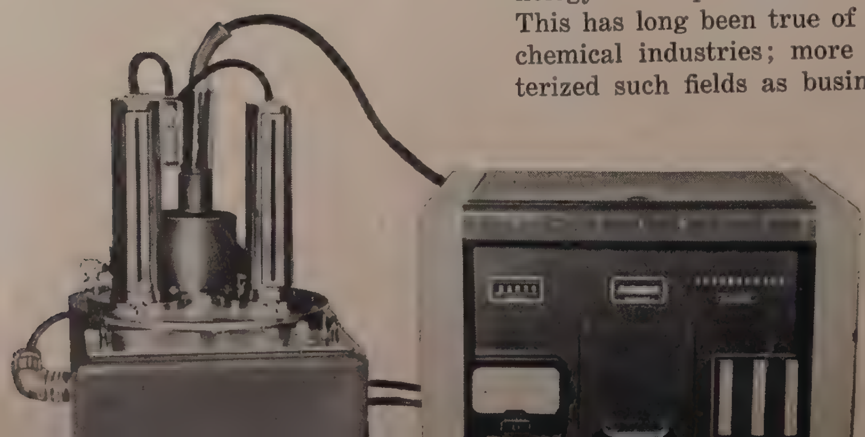
Since the early 1940's industrial research and development has increased at a spectacular rate. Many companies that have given only casual attention to advanced research in the past are now seriously considering the effects of new technological developments on their own operations. And they are depending heavily upon their research and development directors to help guide them into the most profitable areas of work.

The Federal Government's sponsorship of industrial research and development has been a tremendous spur to research in frontier fields. Of the more than $5 billion now spent each year for research, Government expenditures account for about half of the total. Most of this is advanced applied research, primarily for military products. Its significance lies in the fact that it has strongly accelerated overall U.S. research efforts, and added to our technological inventory for ultimate application to commercial as well as military products.

In frontier products research areas particularly, greater acceleration of research activities is becoming increasingly apparent. Frontier products research is basic and applied research on the boundaries of human knowledge; it differs from ordinary research and development activities in two outstanding ways:

- Far more sweeping developments are achieved. Not only new products, but new, broadly applicable technological principles result from it.
- The demand for new products resulting from advanced research and development is stronger and increasing more rapidly than in practically all other fields. Industries based on frontier products research are the "growth" industries of the U.S. today.

Four principal factors underscore the growing importance of frontier products research to industrial concerns. First, since World War II, this type of R & D activity has increased enormously, largely owing to greatly expanded demand for new, never-before-needed types of automatic equipment. Second, many of the results of frontier products research are finding widespread applications for the first time—for example, automatic instrumentation and control systems in the processing industries and electronic computers for general commercial use. Third, many companies have been able to achieve and maintain positions of leadership in their fields of endeavor only through application of advanced technology to the problem of new product development. This has long been true of the chemical and petrochemical industries; more recently it has characterized such fields as business machines, electrical equipment, industrial instrumentation and aircraft. Fourth, more and



A program in frontier products research can make a significant contribution to corporate objectives—if it is intelligently planned and organized. In this article the advantages to a company of advanced research and development are discussed, along with some of the pitfalls that can be avoided through proper planning and organization. Also considered are the important management problems involved with special emphasis on "do's" and "don't's" for R &D managers.

more companies, many of which have never been particularly research-conscious, have recognized both the need for and the future payoff from advanced research and development, and are instituting planned programs.

Frontier products research will have a tremendous influence on the economy of the future. This influence cannot be translated simply into terms of better armaments and more efficient automated industries. How long people will live, what they will eat and how they will communicate, for example, will all be radically changed and improved by the results of frontier research.

Advantages of Frontier Products Research

The record of companies in frontier fields based on advanced technology is impressive. All kinds and sizes of companies are now participating in frontier products research. Organizations like Du Pont, General Electric and Bell Labs have been long accustomed to extensive fundamental research. More recently companies such as General Mills, IBM, Elgin and Glenn L. Martin, accustomed to research in their regular products, have launched extensive frontier products research. And of interest today are the relative newcomers, companies such as Pfizer, Beckman Instruments, Foote Mineral and Spencer Chemical with major programs in advanced technology.

Many an industrial company is capable of undertaking frontier products research. Aside from the obviously good public relations value, what is a company "buying" when it acquires or launches a frontier products research activity? Fundamentally, a frontier products research operation is one of the primary methods of achieving ambitious long-range corporate objectives. Five major advantages may accrue to companies in frontier products fields as described below.

Growth

Typical producers of frontier products, commercial as well as military, have achieved average growth rates in the postwar period ranging from 15 to 20 percent to more than 100 percent annually. This compares with the average growth rate of all manufacturing companies of five to six percent annually.

For example, since 1949 Collins Radio, prominent in frontier electronics, has grown at an average rate of 49 percent annually. Since 1947, General Precision Equipment and Fansteel Metallurgical have each achieved an average sales growth of 20 percent per year. Other examples of unusually rapid growth among frontier producers include Phillips Petroleum, with an average growth of 15 percent per year since 1940; Lear, Inc., whose sales since 1949 have

increased an average of 40 percent yearly; and Hoffman Electronics, with a yearly sales growth averaging 36 percent since 1948.

Higher Return on Investment

Profitwise, the picture is equally attractive. The payoff in profits comes in terms of return not on sales but on stockholder investment, the crux of the measure of management capability. Pre-tax return on net worth of typical suppliers of advanced types of military equipment ranged from 35 to 80 percent in 1954-55, as compared with 19 to 23 percent for all manufacturing companies. Producers in such frontier commercial products fields as industrial and scientific instrumentation are achieving a pre-tax return on investment (net worth) of 25 to 55 percent.

Stability of Sales and Profits

The rapidly growing companies in frontier products research usually experience less relative decline in sales and profits in periods of economic adjustment. Companies conducting this type of research experienced strong continued growth during the 1949 recession.

R&D Favored by Tax Laws

The corporate tax structure has contributed to research expenditures by industry in two ways. First, a considerable portion, often more than half, of what a company spends on research and development may be charged off for tax purposes. Second, the government is underwriting research costs in a number of frontier products fields—more than one-third of the $3.7 billion annual cost of research conducted by private industry in 1954 was government-financed.

In frontier military work, exploration of the unknown or little known through advanced applied research has been necessary to create practical hardware for national defense purposes, and it has the singular characteristic of being "non-competitive" in that even a GE or a Westinghouse cannot afford to risk such expenditure of talent, money, and other resources on a normal commercial business basis. The fundamentals learned by a frontier products government work contractor are likely to be translatable into commercial product fields of the future and, in more limited instances, to present frontier commercial fields.

Contribution to Man's Advancement

A number of progressive companies, in their long-range planning, are searching for a definition of their basic corporate objectives and business philosophy. A frontier products research program offers a company—and the R & D unit in particular—the opportunity of making a lasting and continuing contribution to the well-being of the U.S. and the world. The opportunities for a company to be of real service, with fully adequate rewards, are nowhere greater than in research-based frontier products fields.

Who Benefits From Frontier Research?

All companies, large and small, can benefit importantly from a well-defined frontier products program. However, it will prove advantageous to two types in particular:

- The company whose previous record of sales growth and profitability has been sound but not especially outstanding. A frontier products research program can contribute greatly to new product development, to extensive product diversification, and particularly to fulfillment of company needs for future development not provided by the present field.
- The company in an industry which is shifting or beginning to shift from relatively slow-moving technological advances to extremely rapid advances in technology. The business machine field is an outstanding example. Prior to 1940, new product development in this industry was characterized by unusually clever engineering innovation, but did not depend to a great extent on scientific research. The postwar development of electronic computers has altered the pattern completely. Research and development in some of the most advanced areas of electronics is now necessary for product leadership in this highly competitive field. Research has become the key to ultimate company survival in the industry.

Problems and Risks

Some major headaches can befall a company that undertakes an ill-prepared entry into frontier fields. The glamour of electronics is too strong for the management of many companies to resist. The results in many cases have been extensive losses and internal organization conflicts.

While the problem of adequate communications is an obvious major difficulty in establishing a sound frontier research program, there are a number of other problems. The most significant pitfall can essentially be summarized as failure in market development. A company, for example, may spend $2 million researching and developing what seems to be a promising product, only to find that the existing market will not allow it to recoup the investment.

Here are some of the specific reasons for corporate failure in fields based on frontier research:

- Inadequate markets
- Amateurish market development
- Lack of corporate resources
- Poor organization planning
- Scattered and hit-and-miss research and development
- Insufficient competence on the part of the research staff

Summed up, no company should toy with research-based frontier products without full consideration of the planning and organization required. There has always been the temptation to venture into the unknowns of industrial pioneering—intuition has paid off in a number of instances in the past. However, advanced technology has now become big business, subject to the much greater payoff that can be achieved through sound planning and organization.

Planning and Organizing a Frontier Products Program

Many an industrial company is capable of undertaking frontier products research, but the odds on the success of this transition vary according to the extent of sound planning and organization employed by astute management. The R & D manager's prime responsibility in this area is not only to participate in the planning, but also to provide and translate the technical answers required.

In a planned program in frontier fields, specific goals should be established for the frontier products efforts. Everyone involved should know what these goals are and what the program will ultimately contribute to the future of the company.

Company efforts to expand in frontier products should be concentrated in two or three selected fields in which a position of real leadership can be attained. This avoids the "scattering of shots" in a number of unrelated frontier fields which is typical of some companies doing contract research and development work. For many companies, achievement of recognition as a leader in two or three fields of concentration is a major key to a successful company program in advanced technology.

Three activities are most important to a company in successfully carrying out a major frontier products program. The first is the imaginative layout or "blueprint" of the program. The second is the skillful organization and conduct of this specialized work. The third is backing the program with major corporate resources.

The specific elements in planning and organizing a formalized program include first of all, determining the extent of need for frontier products research in the long range program. All companies vary in their requirements for future development. The extent of need for frontier research as a contributor to long range corporate development is determined by an appraisal of the company's past record, projected future performance in its present field, and desired company objectives.

The company's past record of growth and profitability is analyzed and compared with "par" as represented by all manufacturing, individual competitors and the industry in which the company operates. In addition to comparison with par, the extent of need for frontier products research is determined by the desire of management to achieve certain future objectives in sales, profits, and other company needs. Depending upon existing conditions in the company, these objectives might be set slightl

below par, but are most often set considerably above.

Before any really serious consideration can be given to launching a frontier products program as a vehicle for major expansion, full evaluation of the company's corporate strengths, tangible and intangible, must be completed. Frontier products fields which particularly require the existing abilities, skills, assets and character of the organization will provide the best opportunities for development.

In establishing objectives for future development, the problem is to determine specific objectives for the company in sales, profits and other company requirements to be achieved through the frontier products program in five to 10 years' time. Here again, the R & D manager must provide the technical information necessary to arrive at sound conclusions.

Recognition as a leader in two or three compatible growth fields is the key to ultimate leadership in advanced technology in its fields of interest. Market planning is therefore vital in selecting broad but well-defined frontier product fields with sound future market prospects. All parts of the organization must understand that practical fulfillment of market needs is the ultimate control of their work.

A well laid-out, coordinated program is essential. The program should be integrated into a total long-range plan for future company development, particularly into any program of product diversification and any product development program of the existing business.

There are, of course, alternative methods of entering frontier fields. Management should determine whether frontier product development, product acquisition or company acquisition, or a combination of all three is most suited to the company's needs. Company acquisition, combined with an integrated research and development program in the selected frontier fields, is often the best combination for speed and low cost in achieving desired results.

Management Problems Involved

Development of a successful program in frontier products research is a taxing management job. Many of the management practices successfully employed in the development, manufacture and marketing of "ordinary" products cannot be readily applied to a frontier products program because of the specialized problems peculiar to frontier operations.

Five outstanding problems which must be overcome are the following:

1. The question of which fields the company should concentrate in. This is perhaps the most crucial continuing question that faces both research and general management in the operation of a frontier products program.

2. The provision of a climate within the organization which fosters creativity and new ideas while, at the same time, exercising management control over the research activity.

3. The complex and often opposing interrelationships of research and development with manufacturing, marketing and general management of a frontier products activity.

4. The control of projects from the standpoint of time. In frontier products work particularly, proper timing of the launching and execution of research projects can spell the difference between success or failure.

5. The need for continuity of research and development expenditures. Frontier fields are characterized by extremely rapid technological progress and concurrent fast product obsolescence. This necessitates a continuous, somewhat inflexible expenditure on research and development to maintain a strong position in the chosen fields.

Special Management Techniques

Operation of a successful frontier products program requires specialized management techniques tailored to the needs of the activity. The first and most essential element, of course, is a well-planned organization team. Four primary factors are involved in planning the organization of a frontier products division: overall organization, general management, research and development, and production engineering.

Where overall organization is concerned, the group approach is vital; general management, research and development, production engineering, and production must work together toward common objectives, clearly understood by all. The pivotal man is the R & D manager, for he is largely responsible for coordination and control of all frontier products research activities.

The production engineering activity bridges the gap between research and development and production. Translation of prototypes coming out of research and development into practical, producible equipment is absolutely vital in frontier products work. The need for adequate personnel and facilities to do this essential job cannot be overemphasized.

In frontier products research, unusual flexibility in organization, manufacturing, and research and development is vital. Crash programs, short runs, new frontier projects requiring extremely rapid utilization of new technologies, all contribute to the need for unusual organizational flexibility.

Proper commercial control of research and development activities is essential in a successful frontier products program. The most successful companies in advanced technology use a small professional planning staff to evaluate new product ideas prior to the launching of extensive research. Normally, there are two stages in evaluating ideas for new frontier products:

Stage I: New ideas are subject to preliminary studies from which necessary market research, engineering studies, and financial appraisal are launched. The professional development planning staff performs and coordinates this work and utilizes personnel from other company departments as required to approve or reject the new idea for further appraisal.

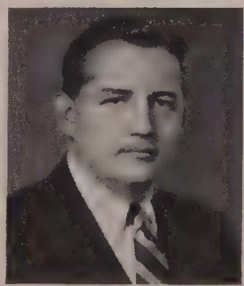
Stage II: Once past Stage I, the new product idea is considered in light of the company's long-range plan for future development. Also in Stage II, further emphasis is placed on evaluating financial and competitive aspects of the new product, company capabilities, the current state of the art, and the needs and plans of prospective customers. A recommendation to top management is then made.

Conclusion

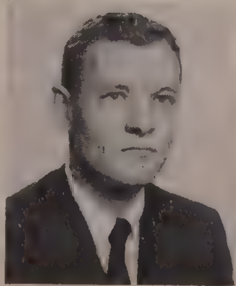
It is not unusual that top management and directors of research and development should now be seeking the proper approach to programs in fields based on frontier research. The planned and organized pattern is a relatively new corporate concept. While it is an established practice with a number of highly successful companies, it is becoming increasingly recognized as a new and specialized technique of management—one that must be adhered to if a frontier products program is to be successful.

The planned approach to frontier products research achieves maximum results. A well-thought out and organized program avoids the possibility of advanced research and development becoming scattered and solely diversionary in time, effort and capital. END

This article was adapted from a talk given before a recent conference of the American Management Association.



William E. Hill is president of William E. Hill & Co., management consultants, New York. He worked for industrial companies in Cuba, Detroit, Pittsburgh and New York before entering the consulting field in 1939.



Warren B. Riley, has been associated with Mr. Hill in the management consulting field since 1948. Previously he held various technical and production assignments in the steel and paper industries.

The Formulation of Proble

Insistence on immediately useful results in return for support of research may be imperiling the lifeblood of scientific progress. What is the answer to the dilemma, since obviously the national economy and our defense effort must depend to a large extent on the results of "utilitarian" research? Prof. Freudenthal says that we should make every effort to focus more attention on the non-utilitarian approach to research for in the long run, it will bear the most fruit. He discusses the principal aspects of problem formulation in light of the theoretical basis of research methodology, independently of any immediate concrete objectives.

Research has many aspects, and it appears differently to different people. The number of those who talk and write about it is increasing much faster than the number of those actually engaged in it. Evidently, much less time and effort is needed to acquire the terminology of research than to acquire sufficient knowledge in any one field to engage in it. While it is reasonable to assume that the only people who know what research is about are those who have actually been engaged in it, there is no denying that the influence on our society of those who talk and write *about* research is much wider than the influence of those who do it.

This is not a new phenomenon. Francis Bacon, who did not amount to much as a scientist, established himself by his writings about science ("Novum Organum") as the recognized spokesman of the utilitarian philosophy of science, a viewpoint that has grown like a snowball in the last three centuries. The doctrine of social utility as the only aim of science and research has gained official acceptance in Soviet Russia; but we should also recognize that in our own country both industry and government are strongly influenced by this doctrine, more strongly, in fact, than we usually care to admit. Contrary to the European tradition, this utilitarian doctrine is not tempered by any inherent respect for learning as such. In fact, many of our industrial and military research administrators would probably be surprised to discover that there *can* be any other philosophy, that motives different from that of "utility" may influence men to choose research as a career, and that neither Archimedes nor Newton were influenced by this motive. When the protagoni of the utilitarian doctrine claim that even Leonardo da Vi in his famous letter to the Duke of Milan offered his technolo cal skill, this only shows that Leonardo's times were not different from our own. Leonardo was aware that "sponsorshi was more easily available for technology, particularly milita technology, than for research for its own sake; it does not me that Leonardo was motivated to invent his different war-machi by their utility. They were the by-products of his interest mechanics. Like Newton, he was driven by a somewhat mysti desire to understand for the sake of understanding. Archimed on the other hand, like Einstein and many of the modern mat maticians and theoretical physicists, was driven by the strong aesthetic motive of creating order by clear logical thought, motive closely related to that driving the artist.

Aesthete, mystic, utilitarian. These are the three faces of t scientific research worker; he may have all three of them only one. His motivation will usually be a mixture of the th basic moving forces; if he is dominated by one motive alc the chances are that he is either a genius or a maniac: the d ference usually depends on the strength of his faith in his o ideas. As Claude Bernard has pointed out, those who have excessive faith in their ideas are not well fitted to make n discoveries. They will tend to be maniacs rather than genius

Motivation in scientific work is very closely related to t question of problem formulation. It is quite obvious that d ferent primary motivation will lead to different ways of cho

n Research

Alfred M. Freudenthal

ing and formulating a problem. The utilitarian, for example, will usually have a definite goal to achieve and thus be mainly concerned with the means of achieving it. His mind goes from the goal to the means, from the question to the solution. The aesthete or the mystic may discover a phenomenon, a fact, or a formal rule, imagining afterwards what it could be useful for. His mind goes from the means to the goal, the answer appearing in fact before the question.

Paradoxical as this may seem, the second kind of approach is not only the more general, but the more fruitful. This becomes increasingly apparent as science advances. It is almost an axiom that in scientific work (as distinguished from industrial development work) practical application is found by not looking for it. But application is important since it opens new questions. Most of the important discoveries appeared to have no practical application at the time they were made, however. This is as true with respect to the form of the ellipse discovered by the Greeks, but only used by Kepler for "practical" purposes 2000 years later, as it is with respect to atomic fission.

One of the most serious deficiencies in the organization of research in our society is that this principle is not recognized. Some of the minds responsible for administrating research funds seem unable to grasp the fact that practical questions are usually solved by means of existing theories, while practical applications of purely scientific discoveries are generally rather remote in time. Within our universities some research is still carried on that has no direct utilitarian motives, although this research is in danger of being destroyed by the overabundance of funds for utilitarian research. Private and government research organizations, by their support of short-term utilitarian research, are cutting off the life-blood of scientific progress. Scientific manpower is being siphoned off which would otherwise be available for fundamental research.

Research Administration and Problem Formulation

Problem formulation depends significantly on administration and organization of research. In this respect the methods developed by industry and government have reached a high degree of efficiency in discouraging original and fundamental research work, while encouraging second-rate derivative "research". One

Born in Poland, Dr. Freudenthal obtained a doctorate in Engineering Sciences in 1930 from the Technische Hochschule in Prague, Czechoslovakia and also studied theoretical physics at Charles University, Prague. He has worked as a structures design engineer. Previously associated with the Hebrew Institute of Technology and the University of Illinois, he is now professor of Civil Engineering at Columbia University.

reason for this is the mistaken belief that the research administrator should be made to understand both purpose and method of the research he is supporting before such work is approved.

Another reason is the belief that effective research must be "planned", "targets" and "target-dates" set and met, "research teams" assembled on the basis of "group adjustment", in short, that research is a commodity for which a manufacturing process can be set up, the product being research reports. In this atmosphere problems are not selected and formulated on their merits or *on the basis of the personal interest of the investigator* in the problem. Selection of the problem is based instead on "sales appeal" to the administrator holding the purse strings and its easy understandability to potential reviewers and referees.

While research must be "administrated", just as any other activity that has reached a certain level of complexity, administration by people who have had no first-hand experience in research but still insist on making research-policy decisions (including formulation of problems) will seriously undermine research activities. Problem formulation is the most important part of a research; only the experienced research worker knows that all successful research is essentially a guessing game in which you not only try to guess at the answer before solving the problem, but possibly even before completely formulating it. And such guessing presupposes a considerable familiarity with the particular sphere of research involved. In fact, once you know enough about the problem to formulate it adequately, you must already have a good qualitative guess at the answer. This applies to problems in mathematics not less than in the natural sciences. There is a definite relationship between the sharpness of formu-

lation of a problem and the number of alternative ways in which the solution may be guessed at. The difficulty of such formulation depends on the sphere of research.

Problem Types

To formulate mathematical problems is relatively easy: the terms are sharply defined, the solution to be acceptable must be unique. Otherwise it will not qualify as a solution.

The formulation of geometrical problems requires a definition of the space in which the problem is to be formulated. while in a particular space the formulation is as rigorous as that of a mathematical problem and the solution as unique, more than one definition of space is possible; alternative solutions for alternative definitions of space will therefore exist.

The geometrical problem becomes a physical problem if the space is assumed to be physical rather than geometrical. This requires the introduction of a relation between the geometric model and the physical reality, which is necessarily an uncertain relation: an answer to a question involving reality cannot be obtained without some margin of uncertainty. This uncertainty covers the unavoidable discrepancy between the geometrical space model and real space, or more generally, between the theoretical model and reality.

The theoretical model may be purely geometrical (involving space alone), physical (involving space, matter and fields) or probabilistic (involving frequencies of occurrence of alternatives). Since the closest approach to constancy of a geometrical or physical parameter in reality is a frequency distribution around an expected value (stochastic limit), all relations established on a model are subject to the uncertainty associated with the "constant" parameters of the model. The formulation of problems involving real space, matter and fields therefore requires a suitable formulation of the uncertainty relations for the different parameters.

Formulating Engineering Problems

In the formulation of physical problems it is usually necessary to start with reality, construct a model of it by abstraction, and solve the problem for this model, applying the solution to the reality for which the problem has been formulated. Since this is so, it is always important to be aware of the stage at which the problem is formulated—that is, whether the formulation applies to reality or to the model. The mathematical pendulum is only a model of the real one, the two dice with the probability of 1/36 to show double six are only models of real dice. All predictions formulated for such models are subject to margins of uncertainty if applied to reality.

The formulation of an engineering or industrial problem differs from that of a physical problem by the larger number of abstractions required to transform reality into a manageable model and by the additional specification of the purpose in operational or economic terms. The relevance of the purpose delimits, in fact, "basic" or "applied" research, and distinguishes the engineering from the physical sciences. The formulation of the problem and thus its solution is strongly dependent on the specified purpose; solutions are obviously no longer unique. Moreover, they usually refer to an oversimplified model obtained from reality by a considerable number of abstractions. They are therefore subject to a rather wide margin of uncertainty. It is this uncertainty which necessitates the relatively large "safety" or "ignorance" factors applied to all engineering operations.

Aspects of Problem Formulation

Problems of applied physics and engineering must be formulated in four different sets of terms, as follows:

- In descriptive terms (semantic formulation)
- In analytical terms (model formulation or hypothesis)
- In operational terms (experimental formulation)
- In statistical terms (formulation of relation between model and reality in terms of operation)

In formulating problems of this type the engineer or industrial research worker is usually too much concerned with the immediate concrete objective to pay attention to the theoretical principles of research methodology. Thus he is hindered in developing the most effective approach to the formulation and solution of his problem, particularly since these methods are generally not the most obvious or the most direct.

The underdeveloped faculty to abstract of many engineers, who are trained in concrete rather than abstract thinking, may be a definite handicap in engineering research, where the complex effects of a number of factors must be evaluated. There is then a danger of what Alfred North Whitehead calls the "fallacy of misplaced concreteness", in trying to describe a phenomenon in terms of an insufficiently known number of relevant factors. When reasoning deductively about a complex phenomenon, a number of factors are usually left out either because of negligence or because of ignorance. The conclusions reached in those cases must therefore be fallacious.

The fallacy of misplaced concreteness is very common in the form of arguments involving "other things being equal". In general, it may be said that all arguments involving such notions are probably fallacious except when the universe of discourse is arbitrarily limited by abstraction, as in mathematics and theoretical science. There is never any reason to suppose that until the conclusions have been well tested, such reasoning can be safely applied to the complex reality of engineering problems.

Another aspect of misplaced concreteness is the acceptance of one particular aspect of a phenomenon as the complete picture. Related to this is the lack of intuitive realization that *by looking from one single point at a single time only a partial picture can be obtained,* and that this picture will become complete only by coordinating observations from *all possible viewpoints and distances at various times.* It is not sufficient to see a phenomenon sharply (that is, closely); it is also necessary to see it as a whole. It is always useful to realize that the closer we look, the more detail we see on a gradually decreasing area until, in the limiting case, we see "everything of nothing".

Thus, in order to obtain an adequate picture of a phenomenon it is *not only necessary to vary the point of view, but also the distance or focus,* so as to coordinate the detail with the whole. Thus, when the engineer considers the material as an aggregate of particles, it is only because from a distance, certain phenomena remain inexplicable or invisible.

Because of his constant concern with "reality", the engineer is frequently not aware of the fact that in observation and experiment, the observer or experimenter and his apparatus cannot be entirely eliminated. *What we see depends essentially on what we look for,* and how well and how long we look; frequently it also depends on what we expect or wish to see. Therefore, it is important to replace sensory observation by measurement, that is, by "pointer reading". While the subconscious interpretation of the sensory perceptions of the observer has thus been eliminated, the conscious interpretation of and inference from the "pointer reading" will necessarily depend on how much relevant information the observer has about the phenomenon and how well his previously formed concepts (frame of reference) explain and predict the results of the experiment or observation. Unless he has formed such a concept (a hypothesis), his data will be not much more than an aggregation of uncoordinated and unorganized facts. (*For a detailed discussion of the role of hypothesis in problem formulation, see page 38.*)

Problem Formulation and Experiment

Three general principles underlie the formulation of a problem in terms of an experiment to answer a question of fact:

1. The meaning of the question must be reducible ultimately to data obtained from "pointer reading" so that conditions are given specifying the exact manner in which *pertinent* observations are to be made;

2. Conditions must be given to make a response to the question possible on the basis of a *finite* set of observations (small sample analysis)

3. Conditions must be given which ensure an indefinite approximation to the answer to the question if the number of experiments is increased ("stochastic limit")

Observation in scientific investigation, however, never designates a purely passive attitude on the part of the observer. The purpose of the observer determines to a large extent what will be observed in any given situation, and particularly which attributes are neglected as inessential (elimination for the purpose of abstraction). The narrowness of the observer's focal point of attention tends to exclude from observation everything not directly connected with the immediate purpose.

Hence, effectiveness of observation depends upon the observer's knowledge of the problem, since observation is not always a simple process of measuring or enumeration; it involves observation of causation when the phenomenon is not directly observed, but only the effect which it produced. Since the significance of research depends on the observation methods, the effectiveness of these methods and the effectiveness of the observer himself are primary considerations in formulating research problems.

Knowledge is obtained directly by experience or observation, or indirectly by inference or deductive reasoning from results of direct observation. Either direct experience or logical arguments are made to justify a certain degree of rational belief about all sorts of conclusions assumed to be significant with regard to the problem considered. The purpose of these attempts is to organize, for subsequent application, the knowledge thus derived, preferably in the form of mathematically formulated relations between significant variables.

The Role of Statistics

Mathematical symbolism is intended to free a presentation from looseness, duplicity and redundancy. That such symbolism implies precision or guarantees accuracy of statement is a delusion from which engineers in particular frequently suffer. No matter how precise the statement appears, a theoretical deduction is no more precise and accurate than the basic assumptions, which are always inferential generalizations from experience. The more complex the problem and the larger the number of operations involved in its solution, the wider the variability of results to be expected, and the more important the application of statistical theory in its formulation.

To simply analyze a set of data collected by the experimenter by applying statistical formulas without further investigation of the original problem, of the method of collecting the data, and of the meaning and pertinence of these data, is a completely inadequate procedure; the statistical analysis becomes a mere arithmetical exercise. To experimentally justify statistical procedures, it is necessary that the statistical hypotheses be pertinent; for instance, why data can be assumed to have a random distribution, or why a certain distribution function can be introduced. Since the answers to these questions are tied to the meaning of the data and the technique of experimentation, they must be given in terms of the formulated (non-statistical) problem. This is the meaning of the postulate that a statistical hypothesis should be the consequence of a formal scientific theory or hypothesis and a selected procedure of experimentation.

Statistical methods help the experimenter to acquire knowledge about a fundamental but not clearly evident system of causes which underlies the experimental or observational data and which might produce similar data in the future. Thus the interest is less in the characteristics of the collected data than in the characteristics of the statistical "population" from which the data are drawn.

If a number of factors affect the phenomenon under investigation, the statistical approach will aid in determining how to combine these factors. Two types of experimenter exist in general: the man who sticks to the single variable and the "changer of everything at once". However, it is of considerable importance that this difference of approach be recognized. The man who in setting up his experiment changes everything at once may in fact not know to which class he belongs. He may be even less aware of the methods at his disposal to perform a valid experiment in spite of his changing so many variables.

On the other hand, there is a deeply ingrained conviction among the more scientifically-minded engineers that unless you vary but one variable, you can never hope to attain significant results. This conviction leads to the setting up of extremely specialized experimental procedures and to an unnecessary multiplication of tests. As always, the best procedure lies in the middle.

Conclusion

An ideal procedure for problem formulation could thus be described as follows: *a formal theory is developed by intuition, formal logic or deduction* (logical inference) from certain presuppositions assumed to be true on the basis of prior knowledge. This theory embodies the concept of observation, and such statistical concepts as distribution functions, randomness and numerical probability.

Pertinent questions are then formulated that can be translated into groups of alternative statistical hypotheses concerning the observations of the selected variables at any given time. These alternative statistical hypotheses are "tested" by deducing from the observations associated with them a judgment concerning the measure of probability of the truth of either hypothesis. Thus the decision to accept or reject the original theory is not based on consideration of "truth" or logical consistency, but essentially on considerations of probability.

This latter distinction is the principal difference between so-called "formal" aspects of science and the "empirical" or "non-formal" aspects of science: the criterion of acceptance or rejection in formal science, such as mathematics, is based on logical consistency, whereas in empirical science, the criterion is essentially one of probability. The rejected alternative is not logically inconsistent and therefore "false", but only improbable with reference to the assumptions made and the experimental evidence considered. Thus the absolute "truth" criterion is replaced by the relative probability criterion which must be supported by a considerable amount of intuition on the part of the experimenter to fill the gap where exact methods are lacking. It is the same intuition, born of a familiarity with all aspects of the problem that can only be acquired through concentration and effort, without which no research problem can be effectively formulated. (*Continued on following page*)

This article was adapted from a talk presented at the Seventh Annual Conference on Industrial Research, sponsored by the Department of Industrial and Management Engineering of Columbia University at Harriman, N.Y., June 11-15, 1956.

THE ROLE OF HYPOTHESIS

The formulation of a (formal) hypothesis or model immediately follows the description of the problem to be solved. And this hypothesis in turn is the basis of the subsequent experimental formulation of the problem since it already defines the principal significant variables. There is no better way to discuss the formulation of hypotheses than to quote Poincaré *(Science and Hypothesis)*:

"It is often said experiments must be made without a preconceived idea. That is impossible. Not only would it make all experiment barren, but that would be attempted which could not be done. Every one carries in his mind his own conception of the world, of which he cannot easily rid himself. We must, for instance, use language; and our language is made up only of preconceived ideas and cannot be otherwise. Only these are *unconscious* preconceived ideas, a thousand times more dangerous than the others.

". . . Thanks to generalization, each fact observed enables us to foresee a great many others; only we must not forget that the first alone is certain, that all others are merely probable.

". . . Every generalization implies in some measure the belief in the unity and simplicity of nature . . . It is, however, not certain that nature is simple. There was a time when the simplicity of a law was an argument invoked in favor of its accuracy . . . although even then Fresnel said in a conversation with Laplace that nature was not concerned about analytical difficulties. Today ideas have greatly changed; and yet, those who do not believe that natural laws have to be simple are still often obliged to act as if they did. They could not entirely avoid this necessity without making impossible all generalizations and consequently all science.

"It is clear that any fact can be generalized in an infinity of ways, and it is a question of choice. This choice can be guided only by considerations of simplicity. Let us take the most commonplace case, that of interpolation. We pass a continuous line, as regular as possible, between the points given by the observation. Why do we avoid points making angles and too abrupt turns? Why do we not make our curve describe the most capricious zigzags? It is because we know beforehand, or believe we know, that the law to be expressed cannot be so complicated as all that.

". . . Ordinarily every law is held to be simple until the contrary is proved. No doubt, if our means of investigations become more and more penetrating, we discover the simple under the complex, then the complex under the simple, then again the simple under the complex, and so on, without our being able to foresee what will be the last term.

"We must stop somewhere, and that science may be possible we must stop when we have found simplicity. This is the only ground on which we can rear the edifices of our generalizations.

". . . What does it matter then whether the simplicity be real, or whether it covers a complex reality? Whether it is due to the influence of large numbers, which levels down individual difference, or to the . . . smallness of certain quantities, which allows us to neglect certain terms, in no case is it due to chance. The simplicity, real or apparent, always has a cause . . .

"All generalization is a hypothesis. Hypothesis, then, has a necessary role that no one has ever contested. Only, it ought always, as soon as possible, and as often as possible, to be subjected to verification. And, of course, if it does not stand this test, it ought to be abandoned without reserve . . .

"Has the discarded hypothesis, then, been barren? Far from that, it may be said it has rendered more service than a true hypothesis . . . If the test does not support it, it is because there is something unexpected and extraordinary; and because there is going to be something found that is unknown and new . . . Thus (the hypothesis) has not only been the occasion of the decisive experiment, but, without having made the hypothesis, the experiment would have been made by chance, so that nothing would have been derived from it. One would have seen nothing extraordinary; only one more fact would have been listed without deducing from it any consequence.

"The firm determination to submit (hypothesis) to experiment is not enough; there are dangerous hypotheses; first, and above all, those which are tacit and unconscious. Since we make them without knowing it, we are powerless to abandon them . . . Let us notice besides that it is important not to multiply hypotheses beyond measure, and to make them only one after the other. If we construct a theory based on a number of hypotheses, and if experiment condemns it, which of our premises is it necessary to change? It will be impossible to know and, inversely, if the experiment succeeds, shall we believe that we have demonstrated all the hypotheses at once?

"We must equally take care to distinguish between the different kinds of hypotheses. There are first those which are perfectly natural and from which one can scarcely escape. It is difficult not to suppose that the influence of bodies very remote is quite negligible, that small movements follow approximately a linear law (which is the result of a general analytical rule that the infinitely small increment of a function is proportional to the increment of the variable . . .), that the effect is a continuous function of its cause. I will say as much of the conditions imposed by symmetry . . . (These hypotheses) are the last to be abandoned.

"There is a second class of hypotheses that I shall term neutral. In most questions, the analyst assumes, either that matter is continuous or, on the contrary, that it is formed of atoms. He might have made the opposite assumption without changing his results. He would only have had more trouble to obtain them. These neutral hypotheses are never dangerous, if only their character is not misunderstood. The hypotheses of the third class are the real generalizations. They are the ones that experiment must confirm or invalidate. Whether verified or condemned, they will always be fruitful." **END**

Research Administration

MERRITT A. WILLIAMSON

We hear a great deal these days about the need for selling our vast output of goods and services. Psychologists have entered the marketing picture, chiefly through studies on the motivations of the buying public ("motivation research"). Because attractive packaging has been found to add greatly to sales appeal, it is rapidly approaching the state of an "art".

It might be worthwhile to examine this month the matter of "selling" as it affects the research and development manager's job. Selling (with apologies to any salesmen who might read this column) may not be a good word choice. To many scientists and engineers it connotes high pressure tactics, loud neckties, wild claims, and alas, perhaps an absence of a highly refined sense of ethics. Beyond a doubt, the word raises the hackles on the backs of some old research dogs. As a substitute for "selling", we might better use the terms persuading or convincing.

From the R & D manager's point of view, there are four types of "buyers". He must sell to:

- His supervision (the management of the enterprise)
- His associates—the division heads of manufacturing, finance, marketing, etc.
- His subordinates
- Everyone else at all levels and in all relationships outside his company

Research: An Intangible Service

Now what is the R & D manager selling? First, he sells intangibles. I know of no area where what is to be sold is more intangible than in research. He is also selling a service to the corporation. The buyers of any service want to know what results will be obtained; furthermore, they are likely to want to see results before they continue buying. Within this framework, the R & D manager also sells attitudes—the underlying philiosophy that gives rise to policy and directives. The better this selling job is performed, the better the division can fulfill its role.

For this column let's consider the job of selling upwards —to the management of the enterprise. In the areas of pure research and non-applied exploratory research we are selling the intangible of intangibles. We are selling the possibility of commercial success five to ten years hence. How can anyone possibly know what will be important, useful, or saleable so far into the future? How can anyone guarantee the success of the work that is planned? Every R & D manager must face up to these problems if he is doing his job. In my opinion no part of his job calls for greater acumen or skill.

Two Essentials for Success

There are, I believe, two essentials for success in selling. The first is rapport with the executive who is in a position to question, block, or approve expenditures for basic studies. Rapport, the dictionary says, is a state of harmonious and/or sympathetic relationship. Where R & D managers have to be in rapport with business men, there must be faith and trust which leads to my second essential for success: high personal and technical integrity.

Where their fields of specialization are far apart (as, for example, when top management is not technically-oriented), understanding of technical competence is complicated at best. Management's only means of getting a bearing on a man's competence is to judge him in those areas where common problems of a non-specialized nature exist; part and parcel of this technique is securing from others in the technical realm an appraisal of the manager's competence.

Without this rapport induced by understanding on both sides high technical skill does not stand a chance of recognition. In selling upwards it is vital that we have rapport with our supervision because in this remote basic research area especially, we can never produce results quickly. Even if a worthwhile result is attained, its significance technically will be overlooked if confidence is lacking.

Where the organization is expected to be doing exploratory research, it is customary for a certain percentage of the available man-hours to be devoted to work which the researcher himself originates and wishes to explore. The percentage varies, but a good average figure would, in my opinion, run between 10 and 20 percent of the research effort. The worker should be free to spend time on work which does not have to be proposed formally, approved, and reported on at regular intervals. Of course, there should always be reports for the record, but these do not need to be scheduled.

In doing this work it should be recognized that out of a hundred ideas explored, only one may be promising enough to warrant a formal proposal for more thorough study. I think it is a mistake to require that these embryonic ideas be discussed with or justified to management. This area should be under the complete control of the R & D manager. His selling job consists of getting appropriations or defending expenditures made in the broad area. In any alert

organization this type of work is going to be done. I think it is better to budget and charge for it separately although it may be carried out as effectively if it is "bootlegged" on other projects.

Challenges and Arguments

What arguments can the R & D manager use if he is challenged by management on these expenditures? For one thing, he can appeal to his successful reputation in the field (the position of authority). For another, he can cite the example of companies who have been successful by permitting this type of work; he may refer to articles in leading periodicals to support this point of view. His best defense may be to point out several successful projects in which management has a current interest and show, if possible, that they originated in this way. He can point out the record of creativity of the persons he has assigned to work in the area. He must be careful, however, not to promise success for each enterprise, and he has to make sure that management understands that success in a commerical sense depends upon many factors that are not under the control of the R & D organization. Where there is a potentially big pay-off management should not object too strenuously to investing a relatively small amount of "sleeping money". Perhaps an outside consulting firm should be recommended. If the consultant is competent and the R & D manager knows his business, his (the R & D manager's) reputation in the company can be considerably enhanced through such an action.

Selling Development and Engineering Work

Thus far we have talked about "selling" management on the support of the basic, fundamental, non-applied, exploratory type of research. Turning to development and engineering work, the selling is not quite as intangible. A project proposal is usually prepared, containing a statement of the expected results and what these results mean to the company. The project can thus be aligned with R & D objectives and corporate policy. The R & D manager or Chief Engineer must of course, be prepared to justify the rate of effort and the expenditures needed to achieve the desired result.

Many a successful R & D executive has obtained approval for work which was justified on immediate results, but which was estimated and planned so that it would include considerable work on unknown and unfamiliar techniques, thus permitting more definite proposals to be made at a later date. If management refuses to move except on very sound and secure projects, the R & D manager must resort to this subterfuge or content himself with turning out a number of mediocre successes of limited value. The selling effort, under any circumstances, should be designed to show some periodic results; this is necessary to forestall criticism that no results are forthcoming. Unquestionably, it is the R & D manager's job and his alone, to "sell" the content and direction of the program and to justify the required expenditures. This job can hardly be delegated.

Forum

This month's case concerns a selling relationship between research management and top management. You are invited to contribute your comments on it for publication in future columns. As you read through the case, you might bear in mind the following questions: What is the real problem? Who is at fault? What techniques could the research director have used to avoid this situation? What principles of management are involved?

Bingo Corporation Case

The Bingo Corporation is one of the country's largest manufacturers of home appliances. The R & D Department had been hard at work on a new and revolutionary appliance for better than three years when it was decided to demonstrate the unit to top management a few weeks before Christmas a year ago. The demonstration was arranged partly at the insistence of top management, who were getting impatient at the long delays in the project and were anxious to see some concrete results.

The project had been fraught with many unforeseen little problems which in many instances called for invention for solution. The original time table had called for a four to five year research program in order to care for these problems and it was clear to the people working in research that at least another year would be required to complete the work. Management had originally "bought" the four year schedule only at the insistence of the Research Director and only after many weeks of argument. The product was so potentially desirable that there was no question of not working on it.

With some misgivings the R & D Department readied for the requested demonstration. A sample was prepared of approximately the same size and shape visualized in the finished product. The many remaining problems were bypassed with clever little gadgets which would serve for the moment but which must be later replaced with "solid" solutions to the problems. More important, some compromises were made with the avowed end product of the research in order to have a demonstration at all. All of these problems, interim solutions, and compromises were carefully documented for top management before the demonstration and every effort was made to be sure that they understood all of these limitations.

The demonstration was given and the product shown was clearly superior to anything available on the market. The management was clearly impressed, in fact greatly elated with what they had seen. A few weeks later large Christmas bonuses were given to all of the people who had worked on the project, and citations were passed out to many of the key personnel on the work.

The research group went back to work on the project with renewed vigor. Things went smoothly for a few months until management again became impatient. The market was ripe for introduction of the new product. The Research Director was on the "carpet" almost daily attempting to justify the length of time consumed by the work. Attempts were made by management to speed up the research process, mainly by such devices as increasing the working day, adding more people to the staff, etc. These methods did increase the amount of work done, but they did not speed up the "rate of invention", hence the project moved no faster.

It is now a year since the demonstration. The project is nearing completion but the market situation is not quite as bright as it was eight months ago. The management feels that research has let them down. Consequently, morale is not good in the Research Department, and the finish to the project is even slower than anticipated. The Research Director is blamed for a "delay" which he originally predicted and indeed strongly argued for.

(Please address your replies to Dr. Merritt A. Williamson, c/o Research & Engineering, 77 South Street, Stamford, Conn. Your name will be withheld on request.)

R/E views the books

Surveys in Mechanics

EDITED BY G. K. BATCHELOR AND R. M. DAVIES.

Reviewed by H. D. Conway, Professor of Engineering Mechanics, Cornell University

For many years, it has been the pleasant custom to mark the arrival of the birthday of a distinguished scientist by the publication of a volume of original research articles written by his students, colleagues and friends and presented in the spirit of a tribute. In the past these volumes have followed a more-or-less set pattern consisting of a short biography, a list of the scientist's publications and the original research articles.

The present volume commemorates the 70th birthday of Sir Geoffrey Ingram Taylor, one of the truly great natural philosophers of our time, and each of the contributions pertains to a branch of mechanics in which Sir Geoffrey has been active during his career. The volume begins with a charming biographical note by Sir Richard V. Southwell giving a fascinating—and sometimes amusing—account of some of the highlights of G. I. Taylor's career. The list of the latter's publications is omitted, since it appears that his collected works will be published in the near future.

But here the usual pattern of anniversary volumes changes. Rather than have a series of research articles whose contents were chosen by the authors, the editors themselves chose the subjects and invited authorities in the various fields to write on them. The result is a series of surveys suitable not only for the scientist actively engaged in the field but also for those readers having the necessary background and desirous of acquiring an overall picture of the state of knowledge as it stands at the present time.

The outcome of this viewpoint has, in the opinion of this reviewer, been a most successful one. A list of the surveys and their authors follows:

- G. I. Taylor: A Biographical Note, by R. V. Southwell
- The Mechanics of Quasi-static Plastic Deformation in Metals, by R. Hill
- Dislocations in Crystalline Solids, by N. F. Mott
- Stress Waves in Solids, by R. M. Davies
- Rotating Fluids, by H. B. Squire
- The Mechanics of Drops and Bubbles, by W. R. Lane and H. L. Green
- Wave Generation by Wind, by F. Ursell
- Viscosity Effects in Sound Waves of Finite Amplitude, by M. J. Lighthill
- Turbulent Diffusion, by G. K. Batchelor and A. A. Townsend
- Atmospheric Turbulence, by T. H. Ellison
- The Mechanics of Sailing Ships and Yachts, by K. S. M. Davidson, New York

As will be seen, the authors were chosen with great care and each article is a gem of its own kind. The book is beautifully produced and is in keeping with the traditionally high standards of the publishers. *Cambridge University Press, 1956, 475 pages, $9.50*

Chemical Market Research in Practice

EDITED BY RICHARD CHADDOCK

Reviewed by John Rivoire, Manager of Market Research, Westvaco Mineral Products Div., Food Machinery & Chemical Corp.

This book is based on the notes for a course of lectures given at Case Institute and at the University of Delaware and represents the combined work of twenty-two expert practitioners in the field. The foundation for this book was laid in 1953 when several members of the Chemical Market Research Association volunteered to deliver lectures on Chemical Market Research at Case. Subsequent revision and editing has produced this compact book, organized in sixteen chapters dealing with general background material on the chemical industry, market techniques, and problems and specific areas such as the plastics industry, synthetic fibers and sulfur.

This little book is well organized and Mr. Richard Chaddock is to be commended for his fine job of editing the diverse contributions of his able colleagues. It is distinguished more for brevity and clarity than for completeness and profundity but it should serve as a highly useful introduction and guide to chemical market research. Despite its brevity, too, it is not superficial and contains several valuable analyses of the chemical industry, market research techniques, and specific market research problems. The quality of its organization and editing are especially evident in the way each chapter sticks to its topic and in the complete absence of repetitions or wondering presentations.

Research executives, whether or not they are directly concerned with market research or with the chemical industry, should find this book of considerable value and those who have some direct concern with market research or responsibility for it will find it virtually indispensable. *Reinhold Publishing Corp., 430 Park Ave., New York, N. Y. 196 pages, $3.00*

Switching Relay Design

BY R. L. PEEK, JR. AND H. N. WAGAR

Reviewed by Arthur L. Kaufman, Barnes Engineering Company

This is an excellent book on the design of reed type relays generally found in telephone service. The material is clearly presented, each chapter leads logically into the next and the nomenclature is carefully defined.

The book is written in two main sections to facilitate use as a text. Other advantages for their purpose are the problems at the end of each chapter and the extensive reference listings. This first section is a simple introduction to the relay problem and discusses: the static force required to reliably close contacts, how their force is produced by electromagnets, the transient performance and its effect on contact closure. Other items such as temperature rise, relay economics, coil design and contact materials are chiefly covered.

The second section reconsiders each topic in greater detail. The chapters on spring dynamics and the magnetic circuit are particularly good and are sufficiently general to be used for reference purposes. The authors are primarily concerned with the extensive analysis of one or two basic relay structures and optimizines their design to meet various requirements such as sensitivity for given voltage loads, closure and release time, reliability and long life. In treating both the static and dynamic states the relay is always assumed to be mounted to a rigid platform acted upon by the electro-magnetic force and its consequences. The work would have to be extended to cover the design of relays

operated under conditions of external shock and vibration.

In view of some recent comment on hermetically sealed relays it is interesting to note their statement that certain insulating materials release organic vapors which, if tapped, combine with the contacts to produce a non-conductive coating. Most telephone relays are not hermetically sealed but are packaged in dust tight enclosure and kept in air conditioned rooms.

Both sections of the book are highly recommended for serious study to persons in the field. The first section would suffice for those only wishing an introduction to the subject. The authors are to be congratulated on a thoughtful and authoritative addition to the Bell Lab series.

D. VanNostrand Inc., New York 464 pages, $9.50.

Distillation In Practice

EDITED BY CHARLES H. NIELSEN

Reviewed by B. C. Raynes, Horizons, Inc.

Distillation in Practice is second in a series of books in progress concerning practical engineering for young chemical engineers. The book is dedicated to the late Charles H. Nielsen as a tribute to his engineering career and to his personal life. Mr. Nielsen guided the selection of the papers given at a one-day meeting in 1954 of the Philadelphia-Wilmington Section of the American Institute of Chemical Engineers on the subject of distillation, the most widely used chemical engineering unit operation. This book is a collection of papers presented at this meeting, and Mr. Nielsen remains as editor despite his untimely death one week later.

Six papers are included in this book. They are:

1. *Over-all Tower Design from a Process Viewpoint*, by C. Pyle, E. I. duPont de Nemours & Company.
2. *Physical Design Features of Plate Columns*, by R. L. Geddes, Stone and Webster Engineering Corp.
3. *Some Techniques in Petroleum Fractionation*, by C. H. Brooks, Sun Oil Company.
4. *Distillation Control*, by W. O'Connor the Lummus Company.
5. *Operation of Distillation Equipment*, by C. E. Strong, Hercules Powder Co.
6. *Some Commercial Aspects of Vacuum Distillation*, by W. A. Hall, Atlantic Refining Company.

These papers are deliberately slanted to present practical experience in distillation rather than to review theoretical considerations. Information is given on the kinds of distillation towers in common usage, practical design considerations, simple rules for the location of temperature and level control points in fractionating columns, and there is a critique of vacuum distillation.

The chapter on operation of distillation equipment is written in a jocular vein and includes some illustrations intended to be humorous, but which detract from the overall tenor of the book.

The young chemical engineer who is preparing to be a supervisor in distillation may find this volume helpful to him in his early experience. It may not ever be included in his library, but for a few months he may want to keep it in his pocket. It measures only 5″ x 7½″ x ½″.

Reinhold Publishing Corp., 430 Park Ave., New York, N. Y. 133 pages, $3.00.

The Principles of Chemical Equilibrium

BY KENNETH DENBIGH

Reviewed by Dr. R. C. Vickery, Section Head of Chemistry, Horizons, Inc.

The aim of this book, an undergraduate study of the general theory of chemical equilibrium, has been well met, not only for use by undergraduates but also by more senior workers whose recollections of fundamental principles are slightly misty. Professor Denbigh has based this book upon obtaining experimental values and their interpretation.

The book is divided into three parts: I, the basis of thermodynamics developed along traditional lines; II, main development of chemical equilibria, reaction and phase equilibria; and III, thermodynamics in relation to the existence of molecules, which contains a short introduction to statistical analogues of entropy and free energy. There is very little to criticise in this book. The mode of presentation is excellent, and, except for Fig. 18, on page 135, which could have been better presented, illustrations and derivations of formulae require no amplification. One great advantage in this book for review purposes lies in the addition at the end of each chapter of problems based not only upon the principles discussed in the chapter preceding but also requiring a general background of previous chapters. This itself makes this book an excellent one for use in the eternal problem of educating undergraduates in *applying* the principles with which they have already been imbued.

With the increasing attention now being paid to the kinetics and principles of chemical equilibrium between complex ions, it would seem preferable that, in the next edition of the book, more attention be given to problems involving such complex ions than the total of one page at present allotted.

These criticisms are, however, minor and this volume is well recommended.

Cambridge University Press, 491 pages, $7.50.

Reference Texts

First National Industrial Directory of Mexico, compiled by Confederation of the Chambers of Industry of Mexico, Publicationes Rolland Vallarta #21, Mexico 4, D.F., Mexico, 3 Volumes, $21.50 prepaid.

Industrial directory to Mexico lists more than 50,000 recognized companies along with addresses, name of principals, whether firm is manufacture, distributor, importer exporter, etc., trademark directory, declared capital of firm, in Vol. I. Vols. II and III break Mexico's products into categories in alphabetical order with suppliers listed under products.

The Use of Selenium Photocells and Sun Batteries by John Sasuga, International Rectifier Corporation, 1521 E. Grand Ave., El Segundo, Calif.

The basic theory and typical applications of photovoltaic cells is presented chiefly as a guide for the technical experimenter and engineer. With the advent of automation and availability of transistors, new applications for selenium photocells have evolved, in control and safety devices, counters, tape reading mechanisms and monitoring equipment.

Worldwide Radio Noise Levels Expected in the Frequency Band 10 Kilocycles to 100 Megacycles, NBS Circular 557, 36 pages, $0.30 Order from Government Printing Office, Washington 25, D. C.

New prediction of the level and variability of external radio noise of three types; atmospheric, galactic and man-made. Using families of curves, the expected median noise grade charts of the world and related levels of radio noise during four-hour time blocks are given for each season as a function of frequency. This form of presentation provides a measure of noise directly applicable to the "transmission–loss" method of measuring radio propagation.

Working Metals by Electro-Sparking, Dept. of Scientific & Industrial Research, Charles House, 5-11 Regent St., London S.W.1, $0.90 in U. S. A.

An abridged translation of an original Russian work, this book was prepared as a practical manual for engineers, technicians, foremen and others concerned with the operation of electro–spark units. Electro–spark machining is one of the newer techniques for working metals, particularly metals and alloys of great hardness. Covers the physical law governing the technique, technological requirements for using the process and the results which can be obtained. Includes outline of workshop procedure based on operating experience obtained in Russian factories.

Research Reports

Reports in this section may be obtained directly from the Office of Technical Services, U.S. Dept. of Commerce, Washington, D. C., unless another source is stated.

Heat Resistant Alloys

Alloys studied in this report were nickel base binary and ternary systems containing such metals and metalloids as phosphorus, silicon, chromium, manganese, molybdenum, tungsten and iron. These were tested for brazing characteristics and chemical and physical properties.

Development of Brazing Alloys for Heat Resistant Alloys, PB 121001, 73 pages, $2.00.

Corrosion Study

A survey of the literature on corrosion in engine cooling systems containing aluminum has been compiled by the Naval Research Laboratory. The bibliography cites sources from 1926 through June 1955. Each listing is abstracted.

Corrosion in Engine Cooling Systems Containing Aluminum: A Literature Survey, PB 111817, 31 pages, $1.00.

Analogue Computation

A rugged, fast, static method of performing analogue computations utilizing a square loop magnetic core in conjunction with switching transistors is described in this report. Computations are dependent only upon the wave-form of periodic functions and the ability of a high remanence magnetic core to store a given number of volt-seconds for a half cycle of a supply frequency. Appreciable output power can be delivered as transistors in the circuit are used only in the switching modes.

Transcendental Function Analogue Computation with Magnetic Cores, PB 111900, 1 pages, $0.50.

Polymer Studies

Three reports of research for polymers with exceptional thermal stability and chemical resistance. In the first, initial compounding of Kel-F elastomer shows promising compounds for low compression set and chemical resistance were those cured with benzoyl peroxide. Immersion tests in experimental hydraulic fluids indicate that Kel-F may prove useful for aircraft hydraulic system applications up to 400°F.

Study and Evaluation of Kel-F Elastomer, PB 111984, 41 pages, $1.25.

In the second, elastomers were prepared from an experimental liquid polymer formulation derived from a condensation product of mercaptoacetic acid and triethylene glycol. Two general types of elastomers are discussed: one obtained by reaction of the liquid polymer with organic and inorganic peroxides, the other by reaction of terminal mercapto groups with unsaturated aldehydes.

Elastomeric Dithiopolyesters, PB 111949, 25 pages, $0.75.

The purpose of the third was to synthesize fluorine-containing polymers of the polyether type for evaluation as sealants, rubbers, coatings and adhesives. Appreciable quantities of two monomers were prepared by reactions involving the dehydrohalogenation of the corresponding halohydrins.

Fluorine-Containing Polyethers, PB 111-986, 57 pages, $1.50.

Black Chromium Plating

A report on analysis and control of black chromium plating solutions. Two procedures for analysis of a mixture of chromic and acetic acids were found usable. One technique is a modified steam distillation and subsequent titration with a sodium hydroxide solution which gives good results for acetic acid but is time-consuming. The other involves potentiometric titration which gives the percent of chromium as chromic acid as well as the amount of acetic acid. This method is fast and suitable for shop control.

Analysis and Control of Black Chromium Plating Solutions, PB 111830, 19 pages, $0.50.

Meteorological Studies

Three recent reports of Government meteorological research. In the first report, strips of metal foil, dispersed by balloon and aircraft, were tracked by radar to measure wind velocities at altitudes up to 74,000 feet. These wind velocities were compared with those measured over the same altitude range by GMD-1A equipment and radar target tracking. The results indicate promise for obtaining high-altitude winds by this technique.

Experiments Using Window to Measure High-Altitude Winds, PB 111901, 11 pages, $0.50.

The second, an appraisal of the current status of the science, arts and techniques related to atmospheric electricity, includes proceedings, papers, reports and discussions from key workers in this field.

Proceedings on the Conference on Atmospheric Electricity, PB 121004, 225 pages, $4.00.

A number of research papers dealing with the properties of the high atmosphere, auroral physics, ionospheric physics, geomagnetism, cosmic rays, atmospheric structure, composition, and dynamics; ionic layers, airglow and auroral statistics, geomagnetic field, and upper atmospheric nomenclature.

The Atmosphere, PB 111966, 75 pages, $2.00.

Irradiated Food

A non-technical explanation of the current status and expectations of research in food preservation by atomic radiation has resulted from the Second Annual Exhibition on the Peaceful Uses of Atomic Energy. What happens to irradiated foods to allow non-refrigerated storage for extended periods and questions about irradiated food most often asked by the layman are discussed.

U. S. Army Panel Discussion on Radiation Preservation of Food, PB 121103, 27 pages, $0.50.

Sound Spectrograph

This sound spectrograph presents an instantaneous plot of the energy of an audio signal. A permanent graphic recording of the spectral analysis is made on a new type of chemically treated electrosensitive paper. The time dimension is plotted along the length of the paper, the frequency is plotted across the width, and the energy of the individual frequency components is indicated by the density of the recorded marks.

An Instantaneous Sound Spectrograph, PB 111864, 35 pages, $1.00.

Servomechanism Studies

Three technical reports, two on servomechanism research and one on operation of the lab's digital computer. The first: in a unique application of clutches as the prime mover in a servomechanism, it was found that the clutch shows advantages over a servo motor of comparable rating

for several reasons, one being that the control power for a given output power is relatively small compared with the power required in the control phase of a servo motor.

The Magnetic Particle Clutch and its Application to Servomechanisms. PB 111-782, 24 pages, $0.75.

In the second, a full-wave magnetic-amplifier circuit which gives an output that is reversible in polarity or phase is presented in detail.

Full-Wave Reversible-Polarity Half-Cycle-Response Magnetic Amplifiers, PB 111747, 32 pages, $1.00.

The third report is designed for those who wish to program and code problems for solution on the Naval Research Lab Electronic Digital Computer. Explains the fundamental tools available to the coder and lets him apply them to his peculiar computational problems.

Programming Manual for the NAREC, PB 111784, 82 pages, $2.25.

Electronics Research

Three reports. The first is a summary of techniques, materials and component parts that find application in the design of printed circuits.

Printed Circuits, PB 100950, 99 pages, $1.75.

A new theory of magnetic amplifier operation developed at Naval Research Lab is presented. An elementary quasi-mathematical approach is used to demonstrate the application of this theory to known circuits.

On the Mechanics of Magnetic Amplifier Operation, PB 104106, 28 pages, $0.75.

Frequency deviation, frequency stability, and harmonic content in r-c phase-shift oscillators are investigated by means of general equations derived from three- and four-section network types.

Analysis and Design of R-C Phase Shift Oscillator Networks, PB 102595, 120 pages, $3.00.

Titanium Handbook

The information contained in the two-part handbook was collected through literature survey and by personal contact with authoritative individuals and institutions. In part I, three major sections cover titanium production, physical metallurgy and properties. Part II, with two major sections, covers laboratory procedures and fabrication.

Handbook on Titanium, Part I, PB 111631, 210 pages, $3.00. Part II, P B 111873, 161 pages, $4.25

Special Purpose Lubricants

Two reports. The first summarizes research in a project to synthesize and evaluate organometallic and organometalloidal substances for possible use as high-temperature lubricants or related materials. The study eliminates organometallic compounds of tin and lead. Organosilicon compounds of various types are found to show distinct promise.

Organo-Metallic and Organo-Metalloidal High-Temperature Lubricants and Related Materials, PB 111889, 136 pages, $3.50.

The second reports the development of a semifluid grease of the composition designated GLT-700-60 which may have a wide range of applications where icing conditions will be encountered.

The Development of a Rubber-Compatible and Ice-Resistant Lubricant for Aircraft Ordnance, PB 111739, 40 pages, $1.25.

Packaging Research

Three reports. Tests indicate that flange, plug and flexible spout closures are superior in protecting the contents in five gallon containers. Screw type and snap-on closures were not as effective.

Evaluation and Development of Closures for Five Gallon Containers, *PB 111804, 102 pages, $2.75.*

A report on research directed toward obtaining maximum cube efficiency in palletized loads. Efficiencies of nested patterns of cylindrical containers—drums, pails and cans—were evaluated.

Cube Efficiencies of Nested and Non-Nested Cylindrical Containers, *PB 111754, 41 pages, $1.25.*

When a package is assembled using volatile corrosion inhibitors to protect ferrous metal components, there is no known method at present to indicate when the protection drops below a safe level. Two limited methods, both based on a rust-inhibition test of the package atmosphere, were developed.

Package Safety Test for Volatile Corrosion Inhibitors, *PB 111848, 63 pages, $1.75.*

Instructor's Station Guide

What facilities and equipment are needed at the instructor's station for him to best do his job? How should these facilities be designed? The Air Force has compiled an instructor's guide written primarily for specialists in human engineering and education. It consists of sections on methodology, equipment design, inventory of trainee station inputs and outputs, examples of human engineering inadequacies, and two questionnaires for getting necessary information on instructor's stations.

Guide for the Design and Evaluation of the Instructor's Station in Training Equipment, *PB 111879, 207 pages, $5.50.*

INDEX TO ADVERTISERS

PRODUCT PORTFOLIO

Components • Chemicals • Literature
Materials • Instruments • Equipment

rinted Circuit 20

ooxy laminate has lower water absorp-on, low dissipation factor, and higher ond strength and meets MIL-P-18177. : is available in sheet sizes of 39″ by 7″ with thicknesses from 1/32 to ½″. . is supplied as either a standard lami-ate or with copper foil on one or both des for printed circuits.
ational Vulcanized Fiber Co.,
956 Beech St., Wilmington 99, Del.

ransducer Calibrator 21

r wire strain gages, their transducers, d thermocouples. The instrument will librate one-, two- or four-arm gage stems without the necessity of com-icated special hook-ups. All loads ap-ied to a transducer are read directly force, acceleration, torque, pressure, ., and the usual tedious arithmetic is minated in a linearity check. Type C's curacy is ±0.05%.
legany Instrument Co., Inc.
91 Wills Mountain, Cumberland, Md.

anning Spectrometer 22

pable of detecting impurities to one rt per billion is easily adapted for use a flame spectrometer. It has a first der reciprocal linear dispersion of 16 gstroms/mm at the exit slit, with a nimum resolution of 0.2 Angstroms. linear wavelength scanning mechan-n requires only a simple Veeder-Root unter to indicate first order wave-gth.
rrell-Ash Co., 26 Farwell St.,
wtonville 60, Mass.

cket and Tube Holder 24

subminiature tubes combines mount-ease with ability to withstand ere shock and vibration conditions ile still affording adequate heat dissi-ion. The one-piece unit will grip the ndard Eby and Cinch button or press-e subminiature tube sockets and the 3 or T 2x3 subminiature tubes.
as E-E Corp., Bedford Airport,
dford, Mass.

gh Reliability Tube 26

signed for computer service in the ere environments in which airborne l mobile military computing equip-ment must operate, is the *6829*, a 9-pin miniature medium-mu twin triode. It features high-perveance design, low heater power, balanced sharp cut-off characteristics, on-off dependability and long life under cut-off conditions.
General Electric, Schenectady 5, N. Y.

Heat-Shock Resistant Ceramic 27

whose extremely low expansion coefficient and high density enable its use in extreme heat-shock applications up to 2500°F. "Sur-Braze" Grade HT-2 is available as fabricated shapes or as rod, bar, rounds, flats which can be machined by the user.
Technion Design & Mfg. Co., Inc.
262 Mott St., New York 12, N. Y.

Short Circuit-Proof Supply 28

is a dual magnetically regulated power supply which features high line transient regulation, is short circuit-proof and has a continuously variable output of 24-32 volts d-c from 0 to 715 amp. Dynamic regulation is held to within 3% for 10% line voltage and load current step changes at rated load. Static regulation is within 0.2% for 10% line voltage change at full load, and 0.2% for load current variations from 10% to full load. Ripple is within 0.25% at rated load.
Magnetic Research Corp., 200 Center St., El Segundo, Calif.

Disc-Type Magnetic Brake 29

can be mounted separately from a motor. It provides the efficient braking advantages of the disc brake to all equipment manufacturers who cannot use a direct, endbell-mounted unit. Ratings available are 3, 6, 10, 15 and 25 ft. lb. continuous duty—3, 6, 10, 15, 25 and 25 ft. lb. intermittent duty.
Reuland Electric Co., Alhambra, Calif.

Silicone Impregnating Varnish 30

described in an eight-page data sheet. Contains uses, properties, and application procedures for high-temp electrical insulation systems. For use in the coating of electrical coils, armatures and stators in electrical motors, generators and transformers.
Silicones Div., Union Carbide & Carbon Corp., 30 E. 42 St., New York 17, N. Y.

Automatic Advance 31

features in an oscillograph record camera for single-frame recordings which automatically advances film frames in rapid sequence, at random, or at synchronized intervals. Greatly simplifies the problem of making sequential photographic studies of repetitive phenomena such as dynamic stresses and short-term stability of circuits.
Allen B. Du Mont Laboratories, Inc.,
760 Bloomfield Ave., Clifton, N. J.

Fixed-Frequency Magnetron 32

a power-producing component for radar applications, operates in the 34,512 to 35,208 Mc range. Its minimum peak power output is 100 kw. With this output, the pulsed Type *6799* provides high performance over long distances.
Sylvania Electric Products Inc.,
1740 Broadway, New York 19, N. Y.

Shock-Resistant Motor 33

a rugged governor-controlled continuous-duty d-c drive motor with only ±0.3% speed variation is designed for high shock and vibration applications. A gear train reduces shaft speed from 7344 to 1836rpm.
John Oster Mfg. Co., Avionic Div.,
Racine, Wis.

Phosphorus Pentafluoride Source 34

a new diazonium hexaflurophosphate stable at ordinary temperatures decomposes smoothly at 150°C to yield phosphorus pentafluoride and nitrogen as gaseous products and the aryl fluoride as a liquid. The PF_5 generation can be easily accomplished in ordinary laboratory glass apparatus, with a trap to collect the aryl fluoride and the gaseous products can be passed directly into the system wherein the PF_5 is desired.
Research Dept., Ozark-Mahoning Co.,
Tulsa, Okla.

Send new product announcements for inclusion in this section to RESEARCH & ENGINEERING, *Editorial Offices, 77 South Street, Stamford, Conn. Accepted as controlled circulation publication at Orange, Conn. Copyright, 1956. The Relyea Publishing Corp., 103 Park Ave., New York 17, N. Y. Volume 2, No. 7, Section 2, July, 1956.*

Submerged Specimen Cutter 35

a laboratory metallurgical cutter specifically designed to cut under water. By utilizing a slow speed wheel and rigidly holding the submerged sample in proper position, an excellent cut-off is achieved. There is no burning or grain distortion nor is intermediate grinding necessary.
Precision Scientific Co.,
3737 W. Cortland St., Chicago 47, Ill.

Analog-to-Digital Converter 36

of accurate and inexpensive photoscanner design for long-distance transmission of data representing voltage, current and power. By converting data from analog to digital form, it is not subject to varying line conditions, and resultant inaccuracies of readings.
Bendix Aviation Corp., 11600 Sherman Way, No. Hollywood, Calif.

Aromatic Ketone Acetophenone 37

properties, specifications, and reactions in an 8 page bulletin. Acetophenone is an excellent solvent for many gums, resins, dyestuffs, and high-melting aromatic chemicals and can be used as a process solvent under oxidizing as well as reducing conditions. It reacts to form compounds useful as resins, pharmaceuticals, corrosion inhibitors, dyestuffs and in making synthetic rubber.
Carbide & Carbon Chemicals Co.,
30 E. 42 St., New York 17, N. Y.

Molecular Still 38

can simulate on a pilot-plant scale the molecular distillation obtained in costly commercial stills. The large, low-priced centrifugal still permits distillation of heat-sensitive materials with molecular weights up to 1200 with less danger of thermal decomposition than by any other accepted distillation method. Some substances, such as silicones and halocarbons, with molecular weights as high as 4000, can be distilled safely.
Consolidated Electrodynamics Corp.,
1775 Mt. Read Blvd., Rochester, N. Y.

Pressure Pickup 39

operates continuously up to 600°F. Available in both gage and differential types, the unit is ½" in diameter, ¾" long, and weighs 15 grams with 30" of insulated, permanently attached, 4-conductor cable.
Consolidated Electrodynamics Corp.,
300 N. Sierra Madre Villa, Pasadena, Cal.

New High Temperature Accelerometer 40

system for environmental testing consists of an acelerometer and external cathode follower and measures shock and vibration phenomena up to 300°F. without external cooling. Subminiature in size, the system has afrequency response from 10 to 2000 cps and acceleration range up to 300 g's. Sensitivity is 20 microvolts per g, output impedance 200 ohms, while accuracy is 5%.
Gulton Mfg. Corp., Metuchen, N. J.

Structural Adhesive Bonding 41

20-page illustrated brochure on techniques for uniting metal to metal as well as a variety of other hard-to-join materials. Included extensive technical data on recently developed high-temperature adhesives.
Narmco Resins & Coatings Co.,
600 Victoria St., Costa Mesa, Calif.

Interferometer 42

for reliable, acurate calibration of crystal type vibrators measures absolute displacements down to 4 x 10^{-6} inches. Completely self-contained, the unit operates on the Fabry-Perot Principle and employs the fringe disappearance technique.
Gulton Mfg. Corp., Metuchen, N. J.

Scintillation Counter 43

for gamma radiation features an exclusive preamplifier circuit which permits its use with quarter-volt scalers and ratemeters or gamma-ray spectrometer systems. Contains a ¾" x ¾" gamma sensitive sodium iodide crystal, 6292 photomultiplier, preamplifier circuitry, magnetic shielding, and a detachable nose piece collimator.
Nuclear Instrument & Chemical Corp.,
229 W. Erie St., Chicago 10, Ill.

Teflon Coated Yarn 44

for use in high temperature electrical insulation such as aircraft wiring applications where cables have to be pulled through small and rough openings. Other uses: Navy cable, coaxial cable and as a sewing thread to fabricate items for chemical resistance.
L. O. F. Glass Fibers Co., 1810 Madison Ave., Toledo 1, Ohio

Oscillographs 45

with hot stylus or ink writing in two, four, six and eight channels are designed for interchangeability from rectilinear to curvilinear recording.
Photron Instrument Co., 6516 Detroit Ave., Cleveland, Ohio

Coated Steel Wire 46

with up to 10% nickel coat for the lamp, radio and television industry. Brass-coated wire is also available in sizes from 0.072-inch to 0.310-inch.
National-Standard Co., Niles, Mich.

PVC Pipe, Valves and Fittings

in an 8 page engineering memorand covers in detail corrosion resistan general properties, fabricating char teristics and economies for corrosi resistant piping systems.
Peter A. Frasse & Co., Inc., 17 Gra St., New York 13, N. Y.

Heat Resistant Stainless Steel

castings designation chart simplifies t selection of any heat resistant stainl casting for its application. Includes ty cal mechanical properties, notes on th application and a chart of some typi high-temperature properties of seve heat resisting alloys. Creep stress d are included. Bulletin 156-H.
Empire Steel Castings, Inc., Readi Pa.

New Precision Rolling

service on metal strip with thickne tolerances held as close as 0.0001". Ma imum widths of 4" can be accomm dated and after rolling, can be slit any desired width.
Handy & Harman, 82 Fulton St., N York, N. Y.

Oil Seals

new in design and compounded fr Chemi-gum rubber, a butadiene acry nitrile elastomer for general use in moving machinery such as automoti farm implements, appliances, hea duty machinery and hydraulic system Permits successful application at tem eratures up to 250°F with a wide ran of commercial multi-purpose oils.
Yale Rubber Co., Sandusky, Ohio

Seawater Magnesia

only commercially available mater combining high surface area (120 squa meters per gram), uniformly large po size and mechanical strength with high degree of basicity and an ion crystal structure. Sea Sorb 43 is ava able in laboratory quantities ($4 a lb. $17.50 per 5-lb lots). Useful for cat lysis, chromatography, purification, r fining and decolorization dehydratic isomerization, dehydrogenation (co version of paraffins to olefins).
Fisher Scientific Co., 315 Forbes S Pittsburgh 19, Pa.

Fatty Alcohol

reaction bulletin will acquaint you wi the unlimited posibilities of fatty cohols as raw materials for furth chemical reactions. Some of the ne fatty alcohols included were never man factured before.
Archer-Daniels-Midland Co.,
2191 W. 110 St., Cleveland 2, Ohio

O-Rings **53**

molded of fuel resistant compound suitable for minus 65°F.
Rubber Products Div., Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, Ohio

Thin Teflon Tape **54**

only 0.0005" thick for use in capacitors, transformers, and for both wrapped and sintered wires and cables. Widths from ½" to 12" are wrapped to 6" o.d. and 1⅛" diameter spools. Samples of the 0.0005" tape are available.
Enflo Corp., Route 38, Airport Circle, Pennsauken, N. J.

Ultra-Compact Counter-Chronograph **55**

combines a high-speed, high-capacity counter, and a precision chronograph which measures time intervals up to 1 second in length in steps of 1 microsecond. The instrument contains, in addition, a somplete power supply and forced-air cooling system, volume, 0.11 cu. ft., weight, 8½ lbs.
Jacobs Instrument Co., Bethesda 14, Md.

Heat Conductivity Analyzer **56**

for accurate measurement of gases can be manufactured individually to meet the requirements of a particular application. Request Bulletin 119.
Arnold O. Beckman, Inc.,
1020 Mission St., So. Pasadena, Calif.

Tubular Capacitor **57**

encased in ceramic paper will withstand severe humidity. Incorporating a newly developed thermosetting plastic end seal, the new capacitor will pass humidity tests at 90 to 95 % humidity over a period of 750 hours at 40°C, 500 hours at 50°C, and 300 hours at 60°C. Rated operating temperature range for new capacitor is —40°C to 85°C.
United Condenser Corp., 3400 Park Ave., New York 56, N. Y.

Iron Powder Spur Gears **60**

AGMA commercial class four and precision class 1 spur gears made from pure electrolytic iron powder. Because tooth surface finish is equivalent to a ground finish, gear units run quieter, more efficiently. Gears up to one square-inch in cross-section can be produced, with each gear made to specific requirements.
Supermet Div., Globe Industries, Inc., 1466 Cincinnati St., Dayton 8, Ohio. . .

Surfactants **62**

A new 40-page data folder on "Tergitol" surfactants describes seven nonionics and four anionics. Besides the information on physical properties, shipping data, and specifications, performance data are included on wetting, penetrating, cleaning, and sudsing action, and lime soap dispersing power.
Carbide & Carbon Chemicals Co., 30 E. 42nd St., New York 17, N. Y.

Precision Pot **63**

makes use of a double Kelvin-Varley circuit which is automized to give a continuous, precisely linear voltage division. Uses matched resistors instead of a helical coil linearity. It is available in a 5- or 10-turn pot and also a special servo model which allows 180° overtravel on each end to prevent overshoot or end sticking.
Servonics, Inc., 834 N. Henry St., Alexandria, Va.

Perchloryl Fluoride **64**

used as a refrigerant is a colorless gas with a characteristic sweetish odor. On cooling, it forms a colorless liquid which solidifies at -146°C to a white, crystalline solid. When stored in an ordinary cylinder at a temperature of 70°F, the liquefied gas exerts a pressure of only 144 pounds.
Pennsylvania Salt Mfg. Co., 3 Penn Center Plaza, Philadelphia 2, Pa.

Measuring Microscope **65**

which reads direct by vernier to 0.01mm on both the horizontal and vertical scales. Interchangeable microscope and telescope objectives make the instrument easily converted into a small cathetometer with a two-dimension field of 232 square centimeters.
Ealing Corp., Box 90, Natick, Mass.

Fatty Acids **66**

brochure tabulates specifications and components of Croco stearic, oleic, tallow and vegetable fatty acids.
A. Gross & Co., 295 Madison Ave., New York 17, N. Y.

Oil-Resistant Rubber **67**

designated as "Chemigum N6B" was developed to meet increasing demand by industry for oil-resistant rubbers in applications where color or non-staining properties are of paramount importance.
Chemical Div., Goodyear Tire & Rubber Co., Akron, Ohio

Spectrophotofluorometer **68**

for quantitative assay, fluorescent analysis, and identification of compounds in solution throughout the visible and ultraviolet regions. The entire range of 200-800 millimichrons is covered by an activating and a fluorescent monochromator.
American Instrument Co., Silver Spring, Md.

Stable Isotopes **69**

revised inventory and price list is available from Oak Ridge National Laboratory. Revised procedures provide for the outright sale of many enriched stable isotopes to all domestic users. Additional info may be obtained by writing to:
Stable Isotopes Div., Oak Ridge National Laboratory, Union Carbide Nuclear Co., Oak Ridge, Tenn.

Scavenger

for patented chlorinated liquids, known as "Tetraphenyltin", is used to insulate and cool transformers. Also holds promise as a moth-proofing agent. Complete information or a laboratory sample may be obtained by letterhead request.
Metal & Thermit Corp., Rahway, N. J.

Air Driven Stirrer **70**

stirs open or closed vessels in the presence of explosive vapors or liquids. Large-size unit eliminates the hazard of the usual electric motor and rheostat. Air motor is fully enclosed with built-in muffler, and will operate on air pressures as low as 3psi. Variable speed is obtained by varying the air supply.
Labline, Inc., 3070 W. Grand Ave., Chicago 22, Ill.

Automatic Fatigue Testing **71**

by means of an automatic program controller for Baldwin-Sonntag fatigue testing machines can be preset (a) to 10 static load levels in either tension or compression and/or (b) 10 dynamic load levels, each of which can be set (c) for any number of load cycles up to 999,999, (d) sequenced in any desired preset order of load levels for (e) any preset number of sequences.
Baldwin-Lima-Hamilton Corp., Electronics & Instrumentation Div., 806 Massachusetts Ave., Cambridge 39, Mass.

Here's a brief review of last month's advertising in RESEARCH & ENGINEERING as a service to readers.

Relays **100**

designed and engineered to meet the most exacting standards. Over 350 different standard relays from stock.
Potter & Brumfield, Inc., Princeton, Ind.

Weather-Resistant Finishes **101**

can help to eliminate mechanical failures in a machine, since rust and corrosion find easy access to vital parts when the protective finish is not properly applied. Advice on finishes and methods of application.
Tousey Varnish Co., 520 West 25th St., Chicago 16, Ill.

Nuclear Research Reactors 102

in any of three types—the swimming Pool Reactor, Heavy Water Research Reactor, or the Nuclear Test Reactor—may be obtained through a new 7-point program designed to materially aid a company in getting and putting a research reactor to work. Steps in the program include reactor specifications, building study, hazards summary report, manufacture of reactor, reactor installation, and start-up and service.
General Electric Co., Section 191-1B, Schenectady 5, N. Y.

Polyester Film 103

known as "Mylar" embodies an unusual combination of physical, electrical, chemical, and thermal properties. The product can be furnished in laminations to paper, plastics, leather, board, textiles and other materials. It can be embossed, die-cut, printed and processed in many ways. ....
Coating Products, 101 West Forest Ave., Englewood, N. J.

Infrared Moisture Balancer 104

reads percent moisture directly, dries and weighs simultaneously, and measures 25 gram or 5 gram samples, either solids or liquids. Drying is by infrared radiation and weighing is by a sensitive null-point torsion.
Central Scientific Co., 1734 Irving Park Road, Chicago 14, Ill.

Plug-In Unit 105

for wide-band, dual-trace applications with Type 541 or Type 545 Oscilloscope handles dual-trace applications over a wide frequency range. Vertical response, sensitivity, input capacitance and electronic switching information on request.
Tektronix, Inc., P.O. Box 831, Portland 7, Ore.

Airborne Instruments 106

in miniature satisfy all requirements for high accuracy, light weight and small size. Components include gyros, servo motors, servo and magnetic amplifiers, tachometer generators, hermetic rotary seals, aircraft navigational systems, and other mechanical, electrical and electronic components.
Kearfott Company, Inc., Little Falls, N .J.

Lithium Compounds 107

display unique solubility and electrolytic properties in organic solvents. Possibilities for the compounds include conductive plastics, low temperature electrolytes, static leakage and rubber goods, among others.
Foote Mineral Co., 455 Eighteen W. Chelten Bldg., Philadelphia 44, Pa.

Vacuum-Deposited Coatings 108

are described in 31 quick-reference sheets already punched to fit standard files or binders. Information given includes characteristics on reflection, transmission, adherence, hardness, durability, water resistance and other data.
Liberty Mirror Division, Libbey-Owens-Ford Glass Co., Brackenridge, Pa.

Two-Stage Vacuum Pump 109

features advanced design and greater volumetric efficiency. It provides a 230 CFM pump for those vacuum installations where the Kinney Model KMB-1200 was too large.
Kinney Mfg. Division, The New York Air Brake Co., 3642 Washington St., Boston 30, Mass.

Model 21 Spectrophotometer 110

can be used in quality control, in identifying products after reactions, to defeat small amounts of impurities which could not be checked in any other way, to check customer samples, to check final material, and in research work, for determining molecular structure.
The Perkin-Elmer Corp., Norwalk, Conn.

Inorganic Fluorides 111

ranging from Elemental Flourine, the most reactive of all chemicals, to the easily handled, inert gaseous dielectric, Sulfur Hexafluoride, are produced by this company. Other inorganic fluorides are made on a laboratory scale for experimental use.
Baker & Adamson Products, General Chemical Division, Allied Chemical & Dye Corp. 40 Rector St., New York 6, N. Y.

Lithium Dispersions 112

offer industry another research technique once considered impractical. Readily prepared, lithium dispersions prove more stable to air and moisture than the metal itself due to the coating of the dispersing medium. Data sheets describing the methods for laboratory preparation of these lithium metal dispersions are available.
Lithium Corp. of America, Inc., 2697 Rand Tower, Minneapolis 2, Minn.

Radioactivity Measuring Instruments 113

for use in many fields, including medical diagnosis, metabolic research, peroleum research, industrial research, biological chemistry, uranium exploration, and gamma-ray spectrometry.
Nuclear Instrument and Chemical Corp. 243 West Erie St., Chicago 10, Ill.

Elastic Stop Nuts 114

feature a red locking collar and are self-locking and vibration proof. The units are readily assembled, provide positive protection against thread corrosion, and prevent liquid seepage along bolts.
Elastic Stop Nut Corp. of America, 2330 Vauxhall Rd., Union, N. J.

Differential Refractometer 115

records automatically and has a limiting sensitivity of 3 x 10^{-6}. The recorder pen indicates refractive index difference and recorder chart movement is controlled by the mass (volume) of sample passed.
Phoenix Precision Instrument Co., 3803 N. Fifth St., Philadelphia 40, Pa.

Additional Information Form

7-56

(USE THIS FORM BEFORE SEPTEMBER 1)

For more information on products or copies of literature described in the Product Portfolio or in advertisements in this issue, circle the appropriate code number below.

	10	20	30	40	50	60	70	80	90	100	110	120
1	11	21	31	41	51	61	71	81	91	101	111	121
2	12	22	32	42	52	62	72	82	92	102	112	122
3	13	23	33	43	53	63	73	83	93	103	113	123
4	14	24	34	44	54	64	74	84	94	104	114	124
5	15	25	35	45	55	65	75	85	95	105	115	125
6	16	26	36	46	56	66	76	86	96	106	116	126
7	17	27	37	47	57	67	77	87	97	107	117	127
8	18	28	38	48	58	68	78	88	98	108	118	128
9	19	29	39	49	59	69	79	89	99	109	119	129

Clip out and mail to: Research & Engineering
103 Park Avenue
New York 17, N.Y.

Please type or print

Name ....

Title ....

Company ....

Company Address ....

....
Zone No.

YARDNEY SILVERCEL®

. . . for every industry

- **MINIMUM WEIGHT AND SIZE**—six times lighter and five times smaller than conventional batteries of equal capacity
- **LOW INTERNAL RESISTANCE**—designed to meet high current discharge requirements
- **FLAT VOLTAGE CHARACTERISTIC**—no discharge dip at any current drain to end of capacity
- **HIGH SAFETY FACTOR**—Spillage and leakage hazards eliminated; no fumes during charge and discharge cycles
- **MECHANICAL STRENGTH** —High resistance to shock, vibration, rapid acceleration and deceleration
- **WIDE TEMPERATURE RANGE**—Efficient at 160°F. and as low as —60°F.

Table of Yardney High-Rate Models

Yardney Silvercel	Nominal Capacity	Peak Pulse Discharge	Weight (ounces)	H. (all in inches)	W.	D.	Used in
HR 01	0.1 AH	3 amps	0.15	1.38	.61	0.20	Instrumentation
HR 05	0.5 AH	30 amps	0.70	1.52	1.10	0.55	Telemetering
HR 1	1.0 AH	45 amps	0.79	1.98	1.08	0.54	Motor-Driven Recorders
HR 3	3.0 AH	75 amps	2.98	2.86	1.72	0.59	Tow-Target Drones
HR 5	5.0 AH	75 amps	4.24	2.95	2.08	0.80	Photo-Flash, Camera Drives,
HR 10	10 AH	220 amps	7.88	4.78	2.32	0.74	Portable Lights, Missile Guidance
HR 20	20 AH	500 amps	13.82	4.28	2.05	1.73	Missile Power Sources and
HR 21	20 AH	500 amps	15.02	7.56	2.31	0.81	Servo Controls
HR 40	40 AH	600 amps	23.20	7.0	3.25	0.99	Torpedo Propulsion
HR 60	60 AH	1000 amps	31.85	4.50	2.75	2.38	Portable TV
*HR 85	100 AH	1900 amps	52.30	9.44	2.81	1.81	Aircraft Power Sources
HR 90	100 AH	1800 amps	51.40	7.0	3.25	2.16	Tow-Target Drones
HR 100	100 AH	2000 amps	44.10	4.78	3.43	2.79	

Write TODAY for technical literature describing physical and electrical characteristics of the complete SILVERCEL line

YARDNEY ELECTRIC CORP.
"PIONEERS IN COMPACT POWER"
40 Leonard St., New York 13, N. Y.

U. S. Patents Granted and Pending

A FEW NAMES FROM OUR SALES LEDGER: U. S. Army, Navy, Air Force, and Bureau of Standards, A.E.C., Bell Aircraft, Bendix Aviation, Boeing Airplane, Clevite-Brush, C.B.S., Fox Movietone, General Electric, Johns Hopkins, Lockheed Aircraft, North American Aviation, Philco, R.C.A., Raytheon, Republic Aviation, Sandia Corp., Sikorsky, Solar, Vitro Corp., Westinghouse Electric and many others.

FOR MORE INFORMATION CIRCLE 120 ON PAGE 48